COMPARISON OF RATE OF FORCE DEVELOPMENT DURING A LIGHT AND MODERATE LOAD SNATCH PULL

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ABSTRACT

Wicki BM, Culici JN, DeMarco NT, Moran MF, Miller JD. Comparison of Rate of Force Development During a Light and Moderate Load Snatch Pull. Journal of Undergraduate Kinesiology Research 2014; (9)2:20-30. Purpose: Rate of force development is an integral factor, which may influence performance in the snatch lift. The first two phases of this lift are referred to as the snatch pull. Conventional training prescription suggests that performing the snatch pull at 30% maximal effort results in an increased lift acceleration as compared to 70%, which results in an increased total mass lifted. The purpose of this study was to measure force development rate during the snatch pull performed at 30% and 70% maximal effort in competitive weightlifters. Methods: Ten competitive male Olympic weightlifters (22.7 ± 3.80 yr) completed a self-selected warm-up, followed by three repetitions of 30% one maximal repetition (1-RM) and 70% 1-RM snatch lift, respectively. Vertical ground reaction force (GRFv) data was obtained from a 6-channel embedded force plate. Results: Statistical analysis revealed a significant difference in peak ground reaction force (PGRF) (p <0.01) between the 30% (1324.43±232.89 N) and 70% (1856.61±213.19 N) trials. No significant differences were noted for average rate of force development (ARFD) (P=0.22) between load conditions (30%: 1157.7±487.07 N, 70%: 1456.01±491.54 N). Similarly, no significant differences were noted between load conditions (30%: 17114.16±5591.37 N, 70%: 19270.73±360.30 N) for peak rate of force development (PRFD) (P=0.27). Conclusion: Results of this study would indicate that snatch pull training at 70% 1-RM requires comparable rates of force production as 30% 1-RM. Results of this study would be of interest for strength coaches and athletes alike attempting to obtain the proper combination of speed and strength during training.

Key Words: Strength, speed, Olympic, power, force
INTRODUCTION

Rate of force development (RFD) is a critical topic for strength coaches and athletes alike. Training to attain the greatest RFD is crucial to superior performance in specific sports (1). One particular sport where RFD is important is Olympic-style weightlifting. Athletes in this sport need to rapidly generate a significant amount of force in order to move heavy loads against gravity. Olympic-style weightlifting typically consists of two exercises; the snatch lift and the clean & jerk. The snatch lift is considered a power exercise consisting of one maximal repetition (1-RM) during competition. The snatch pull is the first two phases of the snatch lift, consisting of the first and second pull. The first pull of the snatch is a slow and controlled motion that occurs until the bar reaches the knee, and the second pull is performed quickly and powerfully starting from above the knee and finishing before the catch or dip phase. The second pull is a combination of powerful hip and knee extension, and to a lesser degree, ankle plantar-flexion while the catch or dip phase is a combination of rapid hip, knee and ankle flexion.

Determining the optimal training load to improve the 1-RM in the snatch has always been of concern to athletes in the sport of Olympic weightlifting (2). Izquierdo et al., utilizing upper and lower body resistance training exercises, reported that explosive strength and power was maximized at 30-45% 1-RM in the upper extremity during the bench press and 60-70% 1-RM for the lower extremities during squats. While the snatch lift relies on a combination of upper and lower extremity strength and power, the snatch-pull is predominantly a lower extremity exercise. Izquierdo et al.’s study would then suggest that explosive strength and mechanical power would be optimized at a 60-70% load during the snatch pull. However, opposed to the snatch pull, the bench press contains a deceleration phase. Therefore Izquierdo et al.’s results from the bench press may not be directly translatable to the snatch pull lift.

Cormie et al. also studied the optimal training load for the squat, jump squat and power clean. Using twelve division 1 male football players, sprinters and long jumpers they determined the peak power output in relation to 1RM and maximal dynamic strength (MDS), calculated as 1RM + [body mass – shank mass], in the abovementioned lifts. The loads for the lifts ranged from 0-90% of 1RM. For the jump squat, they determined the optimal load to be 0% of 1RM (30% of MDS). However, although the peak power output occurred at 0% 1RM, the results were not significantly different between 42, 56, 71 and 85% of 1RM. Similarly in the squat the peak power output occurred at 56% of 1RM (70% of MDS). However, their peak power outputs were not statistically significant across the loading spectrum. In the power clean, both absolute and relative peak power were greatest at 80% of 1RM and were statistically significant form the other loads (15).

Cormie et al. also mentions that the jump squat is a ballistic exercise in which the load is released at the end of motion, resulting in continued acceleration throughout the peak of range of motion. This is quite similar to the snatch pull, as the load is released at the end of motion eliminating the deceleration phase. However, Cormie et al. mentions that the power clean may be the most effective training exercise for athletes required to generate high velocities against heavy loads, such as Olympic weightlifters. This
therefore would give a conflicting range of optimal load in the snatch pull, as similarities to both the power clean and jump squat in particular can be inferred. With 0% of 1RM in the jump squat and 80% of 1RM in the power clean producing peak power output, it strengthens our interest in determining which load produces the greatest RFD in the snatch pull, as one can’t be inferred from the wide range of 0-80% of 1RM (15).

Cormie et al. also mentions how the optimal load of the lift may be dependent on the type of athlete and movement being performed. Jump squats, which yielded a much lower value of peak power output at 0% of 1RM, were suggested for athletes required to move light loads at high velocities, such as sprinters, jumpers, basketball and volleyball players to train with. Power cleans, with a much higher peak power output at 80% of 1RM, were suggested for athletes who need to move heavy loads such as football linemen and Olympic weightlifters were suggested. As our study is also a training study, we want to find which load will produce the greatest RFD in the snatch pull. However many more athletes than just Olympic weightlifters can receive benefit from training with the snatch pull. This increases our interest in the possibility that different athletes may benefit from different loads to produce optimal RFD’s for training purposes during a snatch pull (15).

Comfort and colleagues investigated the peak ground reaction force (PGRF) and peak rate of force development (PRFD) during variations of the hang clean. After comparing the power clean, hang power clean, mid-thigh power clean and mid-thigh clean pull at 60% 1-RM, Comfort and colleagues reported that the mid-thigh clean pull and power clean had the highest PRFD and PGRF (3). While the clean pull and power clean are different lifts than the snatch pull, they share many similar qualities. The first and second pulls of both lifts are quite similar. If PRFD is achieved during the second pull, where the bar placement is between the knee and waist, Comfort and colleagues might lead to the conclusion that PRFD and PGRF in the snatch pull will be achieved at 70% of 1-RM more likely than 30% 1-RM.

While optimal loads for mechanical power appear to be around 70%, lighter training loads have been suggested to decrease odds of injury during preseason without compromising agility in athletes engaged in collision sports (2). Studies looking at higher training loads were also associated with a higher incidence of lower-limb injuries, muscular strains and joint sprains (2). In a previous study by Gabbett & Domrow, increases in training loads, particularly during pre-season, had increased injury risk in collision sports athletes. Training load was calculated by multiplying the training session intensity by the duration of the training session, using a modified rate of perceived exertion (RPE) scale. Gabbett & Domrow also found that reducing training load reduced the risk of injury without compromising agility performance (2). It can then be inferred through Gabbett & Domrow’s findings that a decreased training load does not decrease agility performance. Therefore, when the training load is decreased, acceleration, in this case agility performance, may not be compromised. Consequently, if RFD is not significantly different between a light and moderate load, then the lower load could reduce the risk of injury without compromising performance.
The purpose of this study was to determine whether training with a lighter load with theoretically greater acceleration or training with a heavier load with a greater total mass lifted has a larger influence on RFD during the snatch pull. We hypothesized that the 30% of 1-RM load would produce a greater average rate of force development (ARFD) and peak rate of force development (PRFD). GRFv is hypothesized to be larger in the 70% of 1-RM load. Knowing which load produced greater ARFD and PRFD would therefore aid in the appropriate training load for the snatch pull, as well as possible applications for other athletes and lifts.

METHODS

Subjects
Ten trained Olympic male weightlifters (22.7±3.8 yr) volunteered and granted informed consent for this study. The participants all had at least one year of experience in the snatch lift. Participants were all aware of their current one repetition maximum (1-RM) weight in the snatch lift. Subject reported 1-RM was verified via competition results on www.usaw.org. All lifters were currently training for Olympic-style weightlifting competitions. One repetition maximum for the participants in the snatch lift ranged from 72-120kg.

The study design was approved by the Sacred Heart University Institutional Review Board. Before testing, all participants filled out the American College of Sports Medicine Physical Activity and Readiness Questionnaire. Participants signed the IRB approved informed consent form along with a witness present. All participants verified that they were inherently healthy and free from acute and chronic musculoskeletal injuries.

Procedures
All participants conducted their own self-selected warm up for no longer than 5 minutes. The barbell was then loaded to 30% of 1-RM. Next; the barbell was placed over the force plate. After the participants stepped on the force plate (FP), the FP was tared so only the barbell and not the system of both the lifter and barbell were analyzed. Standardizing the taring to just the barbell and not the system was done to decrease risk of error and increase statistical accuracy, as the static nature of the barbell opposed to the dynamic lifter provided a constant GRFv. GRFv was sampled via NetForce software at a sampling frequency of 200 Hz. Data collection commenced just before the command for the participant to perform the snatch pull. The participants were instructed to release the bar at the end of their lift to further help prevent injury and allow for continued force production without the need for deceleration.

During the initial testing day, the participants conducted four lifts at 30% of 1-RM with three minutes in between each lift. In between lifts, the participants were not allowed to consume any food or beverages besides water. Recovery activity between sets was limited to minimal exertion activities, such as walking, jogging in place or a snatch lift specific motion with no more than a 20-kilogram bar.
Testing day two took place between 72 - 96 hours after the initial testing day to allow for optimal recovery between testing days (5). The participants then conducted four lifts using the 70% of competition 1-RM with the same protocol guidelines as with the 30% of 1-RM load. To account for any confounding effects of participant physical activity between testing days, activity levels were recorded between day one and two using the testing day questionnaire as seen in Table 1.

<table>
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<th>Table 1: Testing Day Questionnaire</th>
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<tr>
<td>1. Describe any physical exertion since the last training session/last week.</td>
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<td>2. Describe your dietary intake in the past 72 hours? Example: alcohol consumption, type of food, fluid intake, meals per day, supplementation, caffeine.</td>
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<td>3. Are you currently on any medications?</td>
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<td>4. What have your sleeping patterns been in the past week?</td>
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<td>5. Any emotional stressors in the past week? Example: test, family/social issues.</td>
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<td>6. Do you smoke? If so, how often?</td>
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**Statistical Analyses**

Custom MATLAB (The Mathworks Inc.; Natick, MA) code was written to compute PGRF and PRFD data at a sampling rate of 200 Hz. Two paired sample t-tests were used to analyze the difference in PGRF, ARFD, GRF, and PRFD during the snatch pull at 30% and 70% of 1-RM. Alpha level was set at P<.05 for all analyses.

**RESULTS**

The results of the paired t-tests indicated a significant difference in PGRF (p <0.01) between the 30% of 1-RM load (1324.43±232.89 N) and the 70% of 1-RM load (1856.61±213.19 N) (Figure 1). No significant differences were found for ARFD (P=0.22) between the 30% of 1-RM load (1157.7±487.07 N) and the 70% of 1-RM load (1456.01±491.54 N) (Figure 3). There were also no significant differences for PRFD (P=0.27) between the 30% of 1-RM load (17114.16±5591.37 N) and the 70% of 1-RM load (19270.73±360.30 N) (Figure 2). No observed differences were noted between the participants testing day questionnaires from Table 1.
Force development and snatch pull

Figure 1. Peak Ground Reaction Force (PGRF) in Newtons (N) between the light (30% of 1-RM) and moderate (70% of 1-RM) load during the Snatch Pull. *significant at P<0.05

Figure 2. Peak rate of force development (PRFD) in Newton-meters/second (Nm/s) between the light (30% of 1-RM) and moderate (70% of 1-RM) load during the snatch pull.
DISCUSSION

We originally hypothesized that the 30% of 1-RM load would produce a greater average rate of force development (ARFD) and peak rate of force development (PRFD.) Our results showed that PRFD and ARFD during the snatch pull were not significantly different between loads of 30% and 70% 1-RM. However, peak ground reaction force (PGRF) was significantly higher in the 70% of 1-RM group. PGRF was expected to be higher in the 70% of 1-RM group due to the heavier load.

Prior studies have looked at rate of force development in college-aged weightlifters. Kawamori et al. conducted a similar study to ours on college weightlifters. Kawamori studied eight male collegiate weightlifters at an average age 21.2 yr +/- 0.9 years, and performed mid-thigh clean pulls at 30-120% of 1-RM power clean. Kawamori et al. found that time to PRFD was achieved at 30% of 1-RM (27,607±4608.3 N•s-1) during a mid-thigh power clean rather than 120% of 1-RM (20,018.5±2814.6 N•s-1), 90% of 1-RM (23472.3±4141.1 N•s-1) or 60% of 1-RM (24086.0±3768.2 N•s-1). Both in Kawamori et al. and our study, PRFD was achieved during the second pull phase of the lift, between the knee and waist (6). While our study did not find a significant difference between PRFD in 30% of 1-RM and 70% 1-RM, both the current study and Kawamori et al. found that PRFD can be accomplished with a load of 30% of 1-RM in these similar lifts.
Wilson et al. reported that training with a load of 30% of 1-RM for the jump squat resulted in greater movement velocity and mean mechanical power output, opposed to an 80% 1-RM load (14). McBride et al. also reported that explosive weight training with a load that maximized the mean mechanical power output of the jump squat resulted in the greatest enhancement in the performance of various dynamic athletic activities (7). The jump squat is similar to the snatch pull in the sense that they are both fast and powerful movements. With these similarities, Wilson et al. and McBride et al.’s findings that a 30% of 1-RM load maximizes the mean mechanical power output and enhances the performance of various dynamic athletic activities, further supports our findings with a 30% of 1-RM load in the snatch pull as being equally as effective as a moderate load such as the 70% of 1-RM used in the current study.

Cormie et al.’s research analyzed the influence of the load-power relationship in the jump squat. The jump squat is similar to a snatch pull in that they are both explosive lower extremity multijoint maneuvers performed in a short period. In the study, 10 recreationally trained male subjects were randomly assigned to a 12-week power-training regimen. At week 0, 6 and 12 of the 12-week training regimen, Cormie et al. had the subjects perform a jump squat with a load of bodyweight, 20kg, 40kg, 60kg and 80kg. Peak power relative to body mass, jump height, peak force relative to body mass and peak velocity were examined. Significant increases were seen in peak power at bodyweight and with a 20kg load. Jump height also had significant increases at bodyweight, 20kg and 40kg, as to be expected. Although we analyzed PRFD and ARFD in our study, the findings by Cormie et al. that peak power is achieved at the lighter loads are consistent with our results that there was no significant difference in ARFD or PRFD between the 30% and 70% of 1RM load during the snatch pull (8).

In a review by Cormie et al., rationale was provided for the optimal load for ballistic movements. Cormie et al. concluded that during ballistic exercises, loads of 0-50% of 1RM appears to be the most potent loading stimulus for improving maximal power in complex movements, such as a snatch pull or jump squat. Cormie et al. also found that loads of 0-60% of 1RM during ballistic and plyometric training resulted in increases in maximal power output during sport-specific movements and improved athletic performance including jumping, sprinting and agility tasks. This would include the snatch pull as a ballistic movement, as the second pull is a form of a jumping task (9).

McBride et al.’s research is some of the limited available research regarding power output in the lower extremity. Much more research has been done regarding power output and RFD in the upper extremity, particularly in the bench press. Jandacka and Uchytil took 15 professional male soccer players and looked at the optimal load necessary to maximize power output in the bench press. McBride concluded that in soccer players, for the development of explosive power during the bench press exercise, the range of loads from 30-50% of 1-RM bench press should be used (7). Siegel et al. also looked at the optimal load to achieve maximal power output in the bench press in 25 college aged male resistance-training participants. Participants 1-RM were determined, then the next day they performed maximal velocity lifts at 50, 70, 30 and 90% of their 1-RM. These bench press lifts were repeated two more times with a rest day in between. Siegal et al.’s research concluded from their results that the
optimal load was 40-60% 1-RM in the bench press to reach peak power output. Izquierdo et al.’s research had 47 male participants divided into two groups with a mean age of 42 and 65yo, and a range of 35-46yo and 60-74yo respectively. Based on participants self-reported 1-RM for bench press, velocity and power during the concentric actions were recorded with no load, 30, 45, 60 and 70% of 1-RM. After a one way ANOVA, Izquierdo et al. found optimal load for power output in the bench press to be 30-45% 1-RM (10).

While Siegel et al., Jandacka and Izquierdo et al. analyzed optimal load for power output in the bench press, their findings further reinforce our results due to the similarities in our studies of percent of 1-RM load with a single repetition exercise working large muscle groups. Although the aforementioned studies were not looking at peak rate of force production in particular, power is a similar variable to peak rate of force production, and one that is also important in Olympic weightlifting.

As mentioned prior, while our subjects were all Olympic-style weightlifters, the snatch pull can provide benefit for many different athletes. A study by Comfort, Allen and Graham-Smith analyzed the kinetic variation during a power clean, hang power clean, mid-thigh power clean and mid-thigh clean pull. Sixteen healthy male rugby players, all with >2 years of structured strength and conditioning training including variations of the clean, participated in the study. The lifts were all performed at 60% of 1RM. Peak GRF and PRFD were significantly greater (p<.001) in the mid-thigh power clean and mid-thigh clean pull as compared to the power clean and hang power-clean. The mid-thigh clean pull and the snatch pull have many similarities, as they both do not involve a deceleration moment and also work the same large muscle groups of the lower extremities. It was also stated that the mid-thigh power clean and mid-thigh clean pull might be more advantageous and provide a practical benefit for less-experienced athletes to perform. As our study was looking at the snatch pull as a training stimulus opposed to a longitudinal study, these results by comfort reinforce the possible benefit of a snatch pull for a variety of different athletes for increasing RFD (16).

However, there are many differences between the bench press and snatch pull. One of which is the bench press being an upper extremity dominant exercise, and the snatch pull being a lower extremity dominant exercise. PRFD, while similar, is still different from power output. While the above-mentioned studies suggest an average of 46% of 1-RM load for maximal power output, our study found no difference in PRFD between the 30% and 70% load (7,11).

There were a few limitations to our study. While most likely not a significant factor, participants did their trials during different times of the day and with different periods of rest between days. Chtouro et al. did not find a significant difference in muscular power strength between evening or morning bouts of anaerobic lower extremity progressive resistance training (12). Chtouro et al.’s findings reinforce that timing of day was most likely not a significant factor in our study. All participants adhered to the 72-96 hour period between trials.

Further research is necessary to apply our results to different populations. In order to be able to generalize the results outside of an athletic population; the current study should
be repeated with other populations including older adults and untrained individuals. Caserotti et al. showed that explosive-type heavy resistance training can be safe and well tolerated even by women in the eighth decade of life (13). Caserotti et al.’s study involved a 12 week progressive explosive type heavy resistance training program twice a week including bilateral knee extension, horizontal leg press, hamstring curls, calf raise and inclined leg press.

Our study is limited due to a small sample size despite active recruitment techniques. Our study is also not randomized which may also have affected our results. Therefore, our results should be interpreted with caution secondary to our limited sample size. Our results are consistent with other literature and serve to be advantageous to strength coaches and athletes alike. Repeating this study but changing the percent of 1-RM tested, due to subject feedback that the 30% of 1-RM load might have been too light, would also be interesting. To eliminate the chance that participants bias their lifts, knowing one was heavier than the other, “blinding” the participants to the weight on the bar would also be something to try if this study was repeated.

CONCLUSIONS

The results of our study indicate a significant difference in PGRF(p <0.01) between the 30% of 1-RM load and the 70% of 1-RM load. No significant differences were found for ARFD (P=0.22) between the 30% of 1-RM load and the 70% of 1-RM load. There were also no significant differences for PRFD (P=0.27) between the 30% of 1-RM load and the 70% of 1-RM load.

The data from our research is applicable to various settings. Theoretically, when training to improve PRFD, a lighter load could be used to produce the same results as a heavier load. Training at 30% would allow greater volume in a training session, decreased risk of injury and less delayed onset muscle soreness (DOMS) than 70% (4,5). However, because correlations do not necessarily imply ‘cause and effect’ relationships, a longitudinal training study should be conducted in order to validate such a suggestion.

This information is especially important to a strength coach, athletic trainer or physical therapist dealing with Olympic weightlifting athletes. This is also significant for younger, elderly, new and recently injured athletes because of the decreased risk of injury involved with the lighter load while still maintaining peak rate of force production. While these results are immediately applicable to the sport of Olympic weightlifting, similar studies have showed comparable results with different populations. Further testing is necessary to apply this data to other populations.

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