BARBELL ACCELERATION ANALYSIS ON VARIOUS INTENSITIES OF WEIGHTLIFTING

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The purpose of this study was to examine how various intensity levels influence the peak barbell acceleration in weightlifting. USA weightlifting resident team members (n=9, men:5 & women:4) participated in this study. They performed two repetitions at intensities of 80, 85, and 90% of 1 repetition maximum (total six repetitions). The peak barbell acceleration was measured at the 2nd pull phase of the snatch/clean. A one-way repeated measure ANOVA was used to analyze the effects of the intensity levels (p = .05). The results showed that intensity has a significant effect on the peak barbell acceleration ($F(2,16) = 11.49$, $p < .001$). The peak barbell acceleration decreased as the intensity level increased (80%: 19.63±3.04, 85%: 16.78±3.56, 90%: 13.65±3.50). Comparison between elite and beginners or other power-oriented athletes can be considered in future studies.

KEY WORDS: barbell acceleration, weightlifting kinematics, weightlifters.

INTRODUCTION: Biomechanical characteristics of weightlifting (in both snatch and clean & jerk) have been studied for a decade. Studies have specifically focused on barbell path in relation to body position, barbell velocity, and mechanical work and power output (Barton, 1997; Gourgoulis, Aggeloussis, Mavromatis, & Garas, 2000; Gourgoulis, Aggeloussis, Kalivas, Antoniou, & Mavromatis, 2004; Haff, et al., 2003; Isaka, Okada, & Funato, 1996; Schilling, et al., 2002; Stone, O'Bryant, Williams, Pierce, & Johnson, 1998). The primary intention of analyzing both kinematic and kinetic variables was to distinguish the difference between a good and bad lift, and analyze the typical lifting techniques of elite weightlifters. However, Stone et al. (2006) concluded that based on these biomechanical variables, it is difficult to predict a perfect lifting technique that is accepted by all weightlifters. For example, it is commonly thought that the barbell path should be close to the body and relatively S-shaped throughout the lift. But some studies reported different barbell paths among some elite weightlifters (Hiskia, 1997). Based on the reviews, the barbell path seems to vary by individual depending on different anthropometric measurement and lifting preference. Another example is that a fast barbell velocity is thought to be a characteristic of good and strong lifters (Gourgoulis et al., 2004; Haff et al., 2003; Stone et al., 1998). However, the fast barbell velocity requires lifters to squat down quickly to be in the catch position, which may lead to an unsuccessful lift. It is questionable to conclude that the faster barbell velocity is a good indication of a successful lift. Rather, the fast barbell velocity may be just one's lifting style. The barbell velocity should be reviewed more carefully in future studies.

Even though the biomechanics of weightlifting have been a well-studied subject, a report of barbell acceleration is limited to only three studies, and no discussion was made regarding the interpretation of the barbell acceleration graph and table in their studies (Gourgoulis, et al., 2000; Haff, et al., 2003; Isaka, et al., 1996). Specifically, the present study focused on the peak barbell acceleration during the 2nd pull phase. The 2nd pull phase is a critical part of the lift to determine whether the barbell is being pulled up to the desired height to catch (Stone, et al., 2006). Furthermore, acceleration is directly proportional to force production while mass is a constant value. Thus, when a barbell increases its rate of velocity, the body is producing the force to accelerate the barbell to an upward direction. This acceleration measurement can be a valuable assessment for weightlifters and other athletes, and it is necessary to examine how various intensities change the peak barbell acceleration. Therefore, the purpose of the study was to examine how various intensity levels influence the peak barbell acceleration in weightlifting. This study hypothesized that the peak barbell acceleration at the 2nd pull phase decreases as the intensity level increases.

METHODS: **Participants:** Men's and women's weightlifting resident team members at Colorado Springs Olympic Training Center participated in this study (see Table 1). They were free of injuries at the time of data collection. They were also in the middle of their strength development phase leading up to the competition. Data were collected in compliance with policies of the United States Olympic Committee on the testing of athletic subjects.

Table 1 Demographic data of participants (*N* = 9)

	Men (*n* = 5)	Women (*n* = 4)
Age (yr)	22.2 ± 3.6	20.3 ± 1.5
Height (m)	1.77 ± 0.12	1.62 ± 0.10
Mass (kg)	100.1 ± 30.2	73.1 ± 19.1

Procedures: All participants reported to the training facility of USA weightlifting for data collection, and were provided the procedure of the testing protocol. They had an adequate amount of stretching and warm-up in a similar fashion as they normally do before the training session. A 3-axis accelerometer (PS-2119, Pasco Scientific, Roseville, CA) was used to measure the barbell acceleration, and was attached to a Bluetooth™ wireless device (Pasco Pasport Airlink SI (PS-2005)). The total weight of the unit is 170.1 grams, which is equivalent to a plastic barbell collar. Thus, the weight of the accelerometer should not interrupt a lifter's ability to sense asymmetry of weight between the left and right sides of the barbell. Recently published data reported that this device accurately measured acceleration as well as a high-speed camera at the same sampling rate (Sato, et al., 2009). Data were collected at sampling rate of 100Hz. In order to minimize the external shock when the lifter drops the barbell, the foam unit was designed to secure the accelerometer (see Figure 1). The accelerometer unit was attached to the end of the barbell. It is important to note that the orientation of the sensor must remain in the constant position throughout the lift to avoid misrepresentation of the resultant acceleration. Therefore, the unit was securely attached directly below the barbell (see Figure 2).

Figure 1 Accelerometer in the foam pad

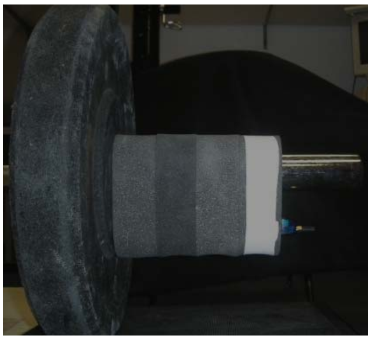

Figure 2 Accelerometer placement

The barbell acceleration data was collected at the intensities of 80, 85, and 90% of one repetition maximum (1RM) (Baechle, & Earle, 2008). Four participants performed snatch and the other five participants performed clean with two repetitions of each intensity level.

Data Analysis: Data Studio™ software (Pasco Scientific, Roseville, CA) was used to acquire, display, and analyze the data. The peak barbell acceleration at the 2nd pull phase was captured from each participant who performed snatch or clean at three different intensity levels. The previous study validated that this peak barbell acceleration is occurring at the 2nd pull phase (Sato, et al., 2009). Each intensity level of the data were then averaged and analyzed with one-way repeated measure ANOVA (*p* =.05) to indentify if there are any effects on various intensity levels on the peak barbell acceleration. Follow-up *T* test was performed with *p*-value of .017 (.05/3). The Statistical Package for Social Sciences (SPSS) was used for the analyses (SPSS, Inc., Chicago, IL).

RESULTS: A one-way repeated measure ANOVA was calculated comparing the intensity levels of 80, 85, and 90% of 1RM. A significant effect was found ($F(2,16) = 11.49$, $p < .001$). Paired-sample *T* tests were used as a protected follow-up *T* test. It revealed that the peak barbell acceleration decreased significantly from 80-85% and 80-90%, but not from 85-90%. Table 1 shows the averaged peak barbell acceleration at each intensity level.

Table 1 Mean peak barbell acceleration at the 2nd pull (m/s^2)

	80%	85%	90%
Average	19.63 ± 3.04	16.78 ± 3.56	13.65 ± 3.50

DISCUSSION: The purpose of the study was to examine how various intensity levels influence the peak barbell acceleration in weightlifting. The results of this study supported the hypothesis that the peak barbell acceleration decreased as the intensity level increased. It is understandable that the increase of the mass of the barbell has an effect on decreasing the barbell acceleration at the 2nd pull phase. The investigators were interested in identifying what intensity level the peak barbell acceleration significantly decreases. During the pilot study, the peak barbell acceleration showed no change from 50 to 80% of 1RM among elite and experienced weightlifters, indicating that the force production becomes greater while the mass of the barbell increased and the peak barbell acceleration remains relatively constant. In this study, the peak barbell acceleration significantly decreased as the intensity level increased from 80 to 85% of 1RM. The results demonstrated that the force affecting barbell acceleration at the 2nd pull phase reaches near maximal level around 85% of 1RM. In other words, the force production remains relatively the same while the peak acceleration decreases and the mass of the barbell increases. The main training intensity during the strength development phase is between 80 to 90% of 1RM (Baechle, & Earle, 2008). These results showed that roughly 80% of 1RM is the threshold for the elite level weightlifters to be able to maintain the peak barbell acceleration. A resultant acceleration was calculated in this study even though the other studies reported linear vertical acceleration (Gourgoulis, et al., 2000; Haff, et al., 2003). Measuring the resultant acceleration was believed to be appropriate since the 2nd pull phase is not typically a linear fashion. Rather, the 2nd pull phase of the barbell path is displayed in curvilinear in many studies (Gourgoulis et al., 2000; Gourgoulis et al., 2004; Haff et al., 2003; Isaka, et al., 1996). The typical resultant acceleration sequence from this study seems consistent with the acceleration figure from Isaka et al. (1996) that the 2nd pull phase exerted the highest barbell acceleration value.

In this study, all participants were experienced and elite level in this sport. Participants were a mix of female and male weightlifters. The difference in the peak barbell acceleration between the genders was not observed. In future studies, it would be appropriate to compare this data with beginner level weightlifters (mainly in youth) and other athletes who require power components in their sports to identify how intensity level influences the barbell acceleration.

Since Olympic weightlifting and its modified versions (power snatch/power clean) are well-utilized in the strength and conditioning field, the investigators discussed possible benefits that some coaches may gain from this analysis. First, attempting the maximal weight is one way to measure how athletes are improving the strength over the long-term training, but tracking the peak barbell acceleration can be another useful assessment to observe progression of the peak acceleration values which equal to the progression of force production capability. Another benefit is that when tracking the peak barbell acceleration throughout a single training session, significant decrease in the acceleration value in later stage of the training session can be an indicator of fatigue (less force is being produced to accelerate the barbell). If the lifter continues to lift after the fatigue sets in, it may lead to over-training/over-use injuries. Describing and identifying fatigue is sensitive and difficult, but the barbell acceleration test may be a suitable assessment to create a better communication environment to re-evaluate the training program between coaches and athletes.

CONCLUSION: Overall, this study tested the peak value of the barbell acceleration at the 2nd pull phase of weightlifting with three different intensity levels. The peak barbell acceleration decreased as the intensity level increased. Since this study was conducted with elite level weightlifters, comparing the data with beginners or other power-typed athletes would be interesting to examine how various intensity levels influence the barbell acceleration.

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