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Thomas P. Murray

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Determining the Optimal Combination of Lifting Method and Intensity  
for Power Production During the Hang Clean

by

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The State University of New York College at Cortland

Submitted in Partial Fulfillment of the  
Requirements for the Master of Science in Exercise Science Degree

Kinesiology Department

STATE UNIVERSITY OF NEW YORK COLLEGE AT CORTLAND

May 2016

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## ABSTRACT

The purpose of this study was to determine the optimal combination of lifting method and load intensity for power production during the hang clean. Twenty college students (18 male, 2 female) performed one set of three repetitions of the hang clean at four different intensities for each method while standing on a force platform embedded in the floor. Intensities were set at 50%, 60%, 70%, and 80% 1RM and the methods tested were Contact, where the participant maintained contact with the force platform throughout the lift, and Jump, where the participant jumped through the pull phase of the lift and became airborne. Each participant performed a total of 24 repetitions. There was a statistically significant interaction between lifting method and load intensity on power production ( $p < .05$ ). Simple main effects were examined and for the contact method power production was significantly different between the four intensities ( $p < .05$ ). Post hoc analyses with a Bonferroni adjustment indicated that power production increased significantly from 50% 1RM to 80% 1RM. Specifically, power production was significantly greater at 80% 1RM than 50% 1RM ( $p < .05$ ). Power production was also significantly greater at 70% 1RM than 50% 1RM ( $p < .05$ ). Power production at 70% 1RM was significantly greater than power production at 50% 1RM regardless of method ( $p < .05$ ). The jump method produced significantly more power at each intensity than the contact method ( $p < .05$ ). In order to maximize power production, it is recommended that when it can be executed safely and correctly, athletes should employ the jump method when performing the hang clean. Until this competency is attained, using the contact method at heavier intensities is indicated to elicit greater power output.

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## CHAPTER 1

### INTRODUCTION

The job description of the strength and conditioning professional includes the requirement to develop strength and power in his or her charges. There are countless combinations of exercises, number of sets, and repetitions performed that can lead to gains in strength for athletes in all sports. To develop power, and especially total-body power, the methods are more defined, in that the athlete must move a given resistance as quickly as possible. Exercises that develop power are quick and explosive in nature and incorporate multiple muscle groups in a coordinated effort. The most common of these exercises are the clean and jerk, the snatch, and the multiple variations of these two Olympic competition lifts. The hang clean is a popular modification of the clean and jerk that is chosen because it is less complicated and safer to perform, and also because it incorporates a quick change of direction which is an important aspect of all sports that require rapid power production. Currently, there is debate as to whether more power is produced when the athlete keeps both feet on the floor or when the athlete jumps and becomes airborne while completing the hang clean. There are also many different opinions regarding the optimal load for power production during this particular lift.

#### **Statement of the Problem**

The purpose of this study was to determine which combination of lifting method and load intensity produced the most power during a hang clean. Two different lifting methods were examined: the hang clean and the jump hang clean. For each lifting method, four

different load intensities were examined: 50%, 60%, 70%, and 80% of one repetition maximum (1RM). The specific purpose of the study was to determine which of the eight combinations of lifting method and load intensity produced the most power during the pull phase of the lift.

### **Hypothesis**

It is anticipated that the optimal load intensity for power production will be 70% of the participants' 1RM and that the optimal combination of method and intensity for power production during the hang clean will occur when the participant becomes airborne while lifting 70% of his or her 1RM.

### **Assumptions**

Participants were instructed to perform each repetition with maximal effort regardless of intensity. Since there is no quantifiable measure of effort, it is assumed that direction was followed and each repetition was performed with maximal effort. Assumptions were also made about the general well-being of each participant at the time of testing with regards to proper rest and nutrition.

### **Delimitations**

This study was open to volunteers who identified as having experience in performing the hang clean; there was no minimal experience level set as a requirement for participation. As a result, most of the participants could be considered novices in regards to their respective experience levels. Also, testing sessions were conducted based on the availability of the participants, so there were no controls for the time of day at which testing took place.

## **Limitations**

This study was open to all volunteers regardless of experience with performing the hang clean, and this had several effects on the study. Because of the relative inexperience of the participants, submaximal loads were used for testing in an attempt to avoid any safety concerns; fortunately all testing was completed without an injury. Experience levels also affected familiarity with the lifting methods, whereas some had been taught the jump method while others were performing it for the first time during the study. The age of the participants was also a factor in that most were underclassmen, so they had minimal exposure to the hang clean, if any, before arriving on campus. Resting and nutrition habits of the testing population in this study were not controlled, so it is possible that there were some unknown influences affecting participants during their testing sessions. Finally, the motivation of each participant certainly varied, and each one's desire to be included in this study could have influenced both the effort they put forth and their general state of well-being when they arrived for their testing session.

## **Definition of terms**

**Clean and jerk.** The clean and jerk is an Olympic competition lift that is performed in two parts: the clean and the jerk. The clean begins with a loaded barbell on the floor and the athlete taking a squatting position behind it with his or her feet approximately hip-width apart and arms fully extended, grasping the barbell with an overhand grip. From this position, the athlete lifts the barbell by extending the knees in a controlled manner, keeping the barbell as close to his or her body as possible. Once the barbell is just above the knees, the athlete performs an explosive plantar flexion of the ankles and extension of the knees and hips, which raises the barbell up to the level of the clavicle where the barbell is caught

by resting it across the anterior deltoids with the upper arms parallel to the floor. From this position, the jerk is initiated by flexing the hips and knees in order to move the barbell in a straight and downward path. Once a quarter-squat position has been reached, the athlete quickly reverses direction through a forceful extension of the hips and knees, followed by the elbows to move the bar into an overhead position. Simultaneously, the athlete assumes a staggered stance from which he or she must then stand erect with the barbell directly overhead in order to complete the lift.

**Power clean.** The power clean is a variation of the clean and jerk in which only the clean is performed. The execution of this technique can be broken down into two pulls: the first is the movement of the athlete lifting the barbell off the floor, and the second is the movement of the barbell being moved up into the catch position. These two movements are performed in rapid succession and the lift is complete once the athlete is standing erect and in control of the barbell.

**Hang clean.** The hang clean is a variation of the power clean in which the athlete begins the lift in an upright position rather than initiating movement with the barbell from the floor. In order to reach this position, the athlete can either remove the loaded barbell from a rack that is at mid-thigh level or lift the barbell from the floor as if he or she was performing a power clean. In this latter scenario, the athlete would perform the two pulls of the power clean as two separate acts rather than one continuous movement. The starting position has been achieved once the athlete is standing with his or her feet shoulder width apart and knees slightly flexed, arms fully extended and grasping the bar with an overhand grip. From this beginning position, the athlete slowly flexes at the waist, maintaining a slight arch in the back and keeping the barbell as close to his or her body as possible as it travels to

just above the knees. From this position, the athlete rapidly changes direction, performing the second phase of the power clean and catching the barbell on the anterior deltoids.

**Ground reaction forces.** Ground reaction forces (GRFs) are the contact forces applied by the ground to the body.

**Countermovement jump.** A countermovement jump (CMJ) is often used in athletic testing as a measure of lower-body power. In this movement, the athlete begins from a standing position and then rapidly flexes at the knees and hips while dorsiflexing at the ankles and hyperextending the arms behind him or herself. The athlete then reverses the movement and jumps upward by extending the knees and hips, plantar flexing at the ankles, and flexing at the shoulders in the sagittal plane. This action places the athlete in a fully extended position with arms directly overhead while in the air. Measurements for this test include vertical displacement and force production as measured by the sum of the GRFs.

**One-repetition maximum.** A one-repetition maximum (1RM) is the maximal load that can be lifted successfully for a single repetition of a particular weightlifting exercise. Strength training programs are often designed based on an athlete's 1RM for specific lifts, typically squat, bench press, and a variation of the clean and jerk.

**Power.** Mechanical power is defined as the amount of work done over time. Work is the product of the force applied to an object and the displacement experienced by the object due to the application of the force. Simplified, power is the product of the average force and the average velocity.

## CHAPTER 2

### Review of Literature

The purpose of this study was to determine the optimal combination of lifting method and intensity for power production during the hang clean by measuring the ground reaction forces produced during multiple trials of each method at various loads. This method of data collection was proven to be both valid and reliable in previous studies (Comfort, Allen, & Graham-Smith, 2011a; Comfort, Fletcher, & McMahon, 2012; Hori et al., 2007; Kawamori et al., 2005; Souza, Shimada, & Koontz, 2002; Suchomel, Beckham, & Wright, 2014; Suchomel, Wright, Kernozek, & Kline, 2014). The findings of the current study are important because there is debate among strength and conditioning professionals as to which lifting method is superior in terms of power production. The hang clean was chosen for this study because it was simpler to perform and had a lower risk of injury than other variations of the clean. This lift was also chosen because it is initiated from the upright position, which keeps the entire weight of the participant plus the loaded barbell on, or directly above, the force platform for the duration of the lift.

#### **Importance of the study**

The clean and its variations are well established in the literature as being beneficial to athletes, particularly sprinters, jumpers, and those whose chosen sports require a rapid change of direction. Hori et al. (2008) conducted a study on elite level male rugby players in which they were tested on 1RM hang clean, 1RM front squat, peak power and height of a CMJ with and without a 40kg barbell, time in a 20m sprint, and time to complete a 10m

change of direction (COD) drill. The results were analyzed to determine if an athlete who has a high performance in the hang clean also has high performances in sprinting, jumping, and COD. The researchers concluded that the subjects who performed best in the hang clean relative to their own body mass also had the best performances in jumping and sprinting, demonstrated higher maximum strength, and they had a higher power output relative to body mass in both the CMJ and the CMJ with the 40kg barbell. This study also revealed a significant correlation between the absolute value of the 1RM hang clean and performance in the COD drill. This relationship indicates that the more weight an athlete can hang clean, the better his or her performance in the COD drill will be. This has direct applications for athletes who need to change direction quickly in order to be successful at their chosen sport.

Apart from being directly beneficial to athletic performance, the hang clean has also been shown to be effective in enhancing other aspects of training for various athletes. Andrews et al. (2011) studied the effects across multiple sets of pairing either the hang clean or the back squat with CMJs. Using a group of female college athletes representing basketball, hockey, soccer, and volleyball, the researchers measured the effects of the different lifts on vertical displacement. They found that by pairing the hang clean with the CMJ the athletes were able to perform more consistently on the CMJ than through a pairing with the back squat, or by performing CMJs exclusively. Complex training, which is the combination of a heavy loaded resistance exercise followed by a biomechanically similar plyometric exercise (McCann & Flanagan, 2010), is supported by the results of this study. It is a training method that can be prescribed by the strength and conditioning professional to athletes who compete in sports that require explosiveness in the vertical jump, such as basketball and volleyball.

By measuring the GRFs produced during different methods of the hang clean, it was anticipated that one method would prove superior in generating the most power. The results will have practical applications for the strength and conditioning professional when teaching the hang clean because the greater the GRFs that are produced over the same period of time, the greater the power output of the athlete. The hang clean is prescribed primarily for the development of power in the athlete, but also for the promotion of multi-limb coordination. If one method of this lift is proven superior to the other for power production, then performing this preferred method will improve maximal muscular power, as well as a variety of dynamic athletic performance variables (Kawamori et al., 2005).

### **Safety**

When working with athletes, be it for training or testing, concern for their safety is paramount. While there are inherent dangers in weightlifting, as an activity it has been proven to be safer than many popular sports. In fact, as of 2008, there has been no scientific evidence to indicate that properly performed and sensibly progressed weightlifting movements performed during practice or competition are riskier than other sports and activities in which youth regularly participate (Faigenbaum & McFarland, 2008). In a 1994 study, Hamill surveyed British public schools to determine the injury rates per 100 hours of participation of the sports and activities offered by the schools. It should be noted that within this study there was a distinction made between weightlifting and weight training. Weightlifting was defined as competition in the snatch and clean and jerk and its associated weight training, while weight training was defined as progressive resistance exercise with machines, or free weights, for body conditioning to achieve fitness, strength, or improvement in other sports. From the survey data, it was determined that weightlifting had

an injury rate of .0013, which was considerably less than sports that are considered to be non-contact, and therefore safer, such as track and field (.03), soccer (.014), and even weight training (.0035). The author also reported the injury rates for American sports, including football (.10), gymnastics (.044), and basketball (.03), all of which have greater rates of injury than weightlifting (.0017), which again proved to be safer than weight training (.0035).

While there is no research into the safety of the hang clean specifically, there have been investigations into how weightlifting injuries occur. Myer, Quatman, Khoury, Wall, and Hewett (2009) compared the mechanisms of weightlifting injuries presented in emergency rooms by youths and adults. Meyer et al. discovered that nearly 40% of the injuries reported were caused by accidents in the weight room, such as pinching fingers between weights or dropping weights on the toes. The authors determined that these types of injuries are potentially preventable with increased supervision and stricter safety guidelines. The present study employed qualified supervision and adhered to appropriate safety protocols in an attempt to eliminate the possibility of accidental injury. The use of a submaximal load during data collection also decreased the possibility of an overuse injury occurring.

### **Selecting the lift**

When selecting the lift for this study, the hang clean was chosen over the power clean because it is a safer lift to perform. The reduced risk is due to maximal loads being higher when performing the power clean than when performing the hang clean (Duba, Kraemer, & Martin, 2009). The hang clean was also selected because of its relative simplicity when compared to the power clean. Since the athlete begins the hang clean from an upright

position rather than with the barbell on the floor, there is less movement required to complete the lift. The selection of the hang clean was also influenced by previous studies (Hakkinen, Kauhanen, & Komi, 1984; Souza et al., 2002) that showed that the greatest GRFs are produced during the second pull of the power clean. Given that the hang clean is the second pull of a power clean, GRFs can be maximized without jeopardizing the safety of the participants.

### **Measuring ground reaction forces**

Numerous studies have measured GRFs during variations of the clean by use of a force platform. Comfort, Allen, and Graham-Smith (2011a) compared the GRFs produced by elite level rugby players as they performed four different variations of the clean. The participants performed the power clean, the hang clean, the mid-thigh hang clean, and the mid-thigh high pull. As indicated by their names, the mid-thigh lifts began with the bar starting at the mid-thigh region, and were performed by pulling the bar up to the deltoids without first flexing at the waist to bring the bar to a position just above the knees. The lifts were performed while the participants stood on a force platform in an environment almost identical to that of this study. Suchomel, Wright, et al. (2014) used a force platform to measure the GRFs of male collegiate track and field athletes performing the hang clean, jump squat, and high pull movements. Kawamori et al. (2005) measured the GRFs produced during the hang clean by means of a force platform on an all-male population that included eight Division II football players, three weightlifters, a rugby player, a bobsledder, a basketball player, and a recreationally trained man. Comfort et al. (2012) utilized a force platform while testing the GRFs of male collegiate rugby, field hockey, and soccer players performing the power clean. Hori et al. (2007) used a force platform to measure the GRFs

during the hang clean and weighted jump squats performed by semiprofessional Australian Rules football players. Collegiate males with at least two years of experience performing the hang clean were studied by Suchomel, Beckham, et al. (2014), with all repetitions being performed on a force platform just as they are in this study. The force platform has been established across multiple studies as a reliable method of recording GRFs produced during variations of the clean and was an appropriate measuring instrument for this study.

These studies have used an assortment of athletes of varying skill levels performing different variations of the clean. The only variation in the design of measuring GRFs with a force platform within the literature was by Souza et al. (2002). In this study, the participants performed the power clean while standing with only their right foot on the force platform. The present study, however, required the participants to stand with both feet on the force platform in order to improve the accuracy of the force measurements.

### **Calculating power**

Numerous studies have calculated power from their GRF data by utilizing the forward dynamics approach (Comfort, Allen, & Graham-Smith, 2011b; Cormie, McCaulley, Triplett, & McBride, 2007; Haff et al., 1997; Hori, Newton, Nosaka, & McGuigan, 2006; Hori et al., 2007; Kawamori et al., 2005; Suchomel, Beckham, et al., 2014; Suchomel, Wright, et al., 2014). This method of computing power has proven to be appropriate and reliable in studies that have measured power output. The procedure is best described in a review by Hori et al. (2006):

From force data, acceleration is calculated by dividing the force by the known mass (barbell mass and lifter's body mass) since force is the product of mass and acceleration. Velocity is calculated from the force data using the impulse-momentum

relationship:  $F \cdot t = m(v_f - v_i)$

Where,  $F$  = force,  $t$  = time,  $m$  = mass,  $v_f$  = final velocity,  $v_i$  = initial velocity.

This process...involves integrating (calculation of area under the curve) the force-time data and dividing by the known mass to determine change in velocity between consecutive samples. A crucial requirement for this analysis is that the initial velocity at the start of data collection be zero. In other words, when data collection starts, the lifter and barbell must be stationary. Power output is calculated by multiplying the measured force by the calculated velocity. (p. 36)

The forward dynamics approach was selected to calculate power in the present study because it had been established in the literature and required only the data derived from a force platform.

### **Selecting the intensities**

Selecting the intensities at which the participants will perform the hang clean was a complex process. The loads needed to be heavy enough to challenge the participants but not so heavy that they affected form and jeopardized safety. Another consideration was that whatever intensities were selected, apart from a 100% 1RM value, there was a risk of the participant not exerting a maximal effort to perform the lift. As discussed in Kawamori et al. (2005), it is possible for a participant to exert sub-maximal force to lift a sub-maximal load; therefore it is up to the experimenter to encourage the participant to perform each lift with maximal effort, regardless of the load. Unfortunately, the level of effort cannot be controlled in an experimental situation, and this condition must be taken into consideration during data analysis.

From the strength and conditioning professional's perspective, performing the hang

clean is an effective way to develop power. Power is defined as the rate of doing work and can be expressed as the product of force and velocity, which has an inverse relationship in concentric muscle actions: as the velocity of movement increases, the force that a muscle can produce decreases. Therefore, the highest power during a movement (peak power) is achieved at a compromised level of force and velocity (Kawamori et al., 2005). The literature is permeated with varying opinions about which percentage of 1RM elicits the greatest power output during the hang clean. For example, a review by Cormie, McGuigan, and Newton (2011) determined that weightlifting exercises performed with loads ranging from 50% to 90% of 1RM appear to produce the best loading stimulus for improving maximal power in complex movements. Moore et al. (as cited in Hori, Newton, Nosaka, & Stone, 2005), however, showed that performing the hang clean at intensities of 70% 1RM or less produced lower power output than that of 75% 1RM or higher loads. In a study to determine the maximal power output during lower-body resistance exercises, Cormie, McCaulley, et al. (2007) concluded that for the power clean, maximal power output occurred at 80% of the participants' 1RM. For the same movement, Comfort et al. (2012) determined that peak power was produced at 70% 1RM in collegiate athletes. More relevant to this study, Suchomel, Wright, et al. (2014) found that peak power output was achieved during the hang clean when the load was set at 65% 1RM. Furthermore, two separate investigations (Hori et al., 2007; Kawamori et al., 2005) independently determined that power output during the hang clean was maximized at 70% of the participants' 1RM. Due to the inconsistent findings, it was determined that the best course of action would be to replicate previous studies with data collection methods similar to the proposed study, and to measure power production across a range of percentages of the participants' 1RM values.

## **Lifting methods**

The literature is bereft of experiments comparing the methods included in the present study. Although there are no similar studies, there is some discussion as to the lifting technique used when performing the clean or one of its variations. Cormie, McCaulley, et al. (2007) disqualified attempts of the power clean if the participant's feet left the platform, which then required the participant to repeat the lift. Rucci and Tomporowski (2010) examined the effects of feedback on performance of the hang clean. In this study, the participants were encouraged to maintain contact with the platform when performing the hang clean, and the lift was considered incorrectly performed if they did not. These studies are contradicted by those of Duba, Kraemer, and Martin (2007, 2009) in which the researchers encouraged athletes to jump when performing both the hang clean and the power clean. These parameters reinforce the notion that there is some controversy as to which lifting method is best for performing the clean. Through the results of this study, it was anticipated that a resolution could be reached about not only which hang clean method develops more power, but also at which percentage of 1RM.

## **CHAPTER 3**

### **Methods**

The purpose of this study was to determine which combination of lifting method and load intensity produced the most power in a hang clean. Two different lifting methods were examined: the hang clean and the jump hang clean. For each lifting method, four different load intensities were examined: 50%, 60%, 70%, and 80% of 1RM. The specific purpose of the study was to determine which of the eight combinations of lifting method and load intensity produced the most power during the pull phase of the lift.

### **Participants**

The study was approved by the SUNY Cortland Institutional Review Board prior to recruiting participants (Appendix A). The study and its risks were described to potential participants, and those who were interested then read and signed an informed consent (Appendix B). The participants for this study were college students of both genders who were experienced in executing the hang clean. The sample was drawn from varsity sports teams that were in their respective off-seasons as well as the general student body. By selecting from this population, the need to teach the hang clean was eliminated, allowing the focus of the experiment to remain on the power generated during each lift instead of coaching each participant through the trials. Another benefit of selecting a sample with prior knowledge of the lift was that only a familiarization with both test methods was required prior to each session.

Table 1

*Participant Descriptive Data*

Participant	Sex	Age	Body Mass (kg)	1RM (kg)
1	Male (B)	19	82	85
2	Male (B)	20	94	80
3	Male (B)	20	97	85
4	Male (B)	21	84	85
5	Male (B)	20	92	110
6	Male (L)	19	81	70
7	Male (L)	18	83	60
8	Male (L)	18	64	60
9	Male (L)	18	75	80
10	Male (L)	18	74	70
11	Male (L)	18	93	70
12	Male (L)	18	92	80
13	Male (L)	18	83	60
14	Male (L)	19	85	85
15	Male (R)	21	91	90
16	Female (R)	21	67	40
17	Female (R)	21	91	45
18	Male (R)	24	88	95
19	Male (R)	23	96	80
20	Male (R)	25	72	100
	<i>M</i>	19.95	84.20	76.50
	<i>SD</i>	2.114	9.639	17.479

*Note.* B = basketball; L = lacrosse; R = recreationally trained.

The participants were 20 healthy athletic college students (mean  $\pm$  *SD* age 19.95  $\pm$  2.114 years, body mass 84.20  $\pm$  9.639 kg, and 1RM hang clean 76.50  $\pm$  17.479 kg). The sample was comprised of 18 males (nine members of the varsity lacrosse team, five varsity basketball players, and four who were recreationally trained) and two recreationally trained females.

## Equipment

As shown in Figure 1, a 60 by 40cm force platform (Bertec Corporation, Columbus, OH) that was embedded in the floor was used to measure the GRFs produced by the participants during the hang cleans. The force platform was calibrated prior to each testing session using standard techniques. The sampling rate for the force platform was set at 1,000 Hz, as established by previous studies (Comfort et al., 2011a, 2011b; Cormie, Deane, & McBride, 2007; Cormie, McBride, & McCaulley, 2009; Cormie, McCaulley, et al., 2007; Dayne et al., 2011).



*Figure 1.* Experimental Setup.

Body mass was measured using a standard manual counterweight scale (Detecto Scales, Incorporated, Brooklyn, NY). Power was calculated by entering the force data into a template created in Microsoft Excel (Microsoft Corporation, Redmond, WA), a method similar to previous studies (Suchomel, Beckham, et al., 2014; Suchomel, Wright, et al., 2014). Statistical analysis was performed using a standard software package (SPSS, Version

23, International Business Machines Corporation, Armonk, NY) installed on an Optiplex 9010 desktop computer (Dell Corporation, Round Rock, TX).

### **Procedures**

Participants performed eight separate sets of three repetitions of the hang clean. For the first four sets, the participants performed the hang clean while maintaining contact with the force platform, followed by four sets where they jumped through the pull and become airborne before landing back on the force platform. The intensity of each set was selected at random prior to the start of the testing session from the chosen testing values of 50%, 60%, 70%, and 80% 1RM. The randomly selected order of intensity was the same for both methods. The participants' 1RM were determined at previous weight training sessions held within one week prior to the scheduled experimental session.

Participants were assigned a testing identification number in order to protect their privacy, and all testing was conducted in a single session per participant. A familiarization session was held prior to testing to ensure that the participants were comfortable performing both methods of the hang clean. Before performing the lifts, each participant's body mass was measured and each participant performed a warm-up of light calisthenics of their choosing and completed three sets of five repetitions at 40% 1RM of the hang clean to reduce the risk of injury, as suggested by Souza et al. (2002). The participant then loaded the barbell with the appropriate weight based on their individual 1RM and prepared to execute the lift by standing still with both feet on the force platform. On cue, the participant performed one repetition of the assigned method and then stepped off of the force platform and had a one-minute rest period before the next repetition. This procedure was followed for the two subsequent repetitions followed by a two-minute rest period before the subsequent

set. The session concluded once measurable data was recorded for all eight sets. Once data collection was completed, each participant's force-time history was examined and the peak force value for the individual sets of both methods was entered into the software for analysis.

### **Power calculation**

The peak power values produced during the trials were computed from the area underneath the force curve as follows:

Output from the force platform was converted to force data with the following formula:

$$F = (O \cdot 20 \cdot g) / 0.53$$

where,

O = output from force platform after amplification

20 = 20 kg mass used to calibrate the force platform

$g = 9.81 \text{m/s}^2$  = acceleration due to gravity

0.53 = calibration factor related to the amplification factor used on the force platform with the amplifier set at "2".

The mass of the participant plus the loaded barbell was then multiplied by the acceleration due to gravity and subtracted from the force value to determine the net force acting on the participant plus loaded barbell:

$$\Sigma F = F - W = (F - (mg))$$

where,

$\Sigma F$  = net vertical force acting on participant plus loaded barbell

$F$  = vertical reaction force measured by force platform

$m$  = mass of participant plus barbell

$W$  = weight of participant and barbell

$g = 9.81\text{m/s}^2$  = acceleration due to gravity.

Change in velocity of the participant plus weighted barbell was determined through the following formula:

$$\Delta v = a\Delta t = \frac{(\Sigma F)\Delta t}{m} = \frac{(F - mg)\Delta t}{(m)}$$

where,

$\Delta v$  = change in vertical velocity during the sampling time

$a$  = vertical acceleration of the participant plus weighted barbell

$\Delta t$  = sample time = 1/600 s

$F$  = vertical reaction force measured by force platform

$m$  = mass of the participant plus weighted barbell

Instantaneous vertical velocity was calculated by adding the  $\Delta v$  value to the instantaneous velocity of the previous sample. The initial velocity of the participant and barbell at the beginning of the lift was assumed to be zero.

$$v_i = v_{i-1} + \Delta v = v_{i-1} + \left\{ \frac{(F_i - mg)\Delta t}{(m)} \right\}$$

where,

$v_i$  = vertical velocity of the participant plus barbell at time  $i$

$v_{i-1}$  = vertical velocity of the participant plus barbell at time  $i-1$

$F_i$  = vertical reaction force measured by force platform at time  $i$

To determine instantaneous power, the instantaneous velocity was multiplied by force:

$$P_i = (F_i)(v_i) = (F_i) \left\{ v_{i-1} + \frac{(F_i - mg)\Delta t}{(m)} \right\}$$

where,

$P_i$  = instantaneous power at time  $i$

$F_i$  = vertical reaction force measured by force platform at time  $i$

$v_i$  = vertical velocity of the participant plus barbell at time  $i$

$v_{i-1}$  = vertical velocity of the participant plus barbell at time  $i-1$

### **Statistical Analysis**

The power values of each successful trial were analyzed and the lowest outputs were eliminated so that each participant had only one peak power value for each of the eight combinations of method and intensity. These values were then entered into the statistical software where a two-way repeated measures ANOVA was performed to determine which combination of method and intensity produced the most power. The statistical significance level was set at  $p \leq .05$ , as has been done in previous studies measuring power with similar methods (Comfort et al., 2011b; Cormie, McCaulley, et al., 2007; Haff et al., 1997; Hori et al., 2007; Kawamori et al., 2005).

## CHAPTER 4

### Results

The purpose of this study was to determine which combination of lifting method and load intensity produced the most power in a hang clean. Two different lifting methods were examined: the hang clean and the jump hang clean. For each lifting method, four different load intensities were examined: 50%, 60%, 70%, and 80% of 1RM. The specific purpose of the study was to determine which of the eight combinations of lifting method and load intensity produced the most power during the pull phase of the lift.

#### **Lifting method and load intensity interaction with power production**

A two-way repeated measures ANOVA was performed to determine if lifting method and load intensity had an effect on power production during the hang clean. There was a statistically significant interaction between lifting method and load intensity on power production,  $F(3,57) = 3.034$ ,  $p < .05$ , partial  $\eta^2 = .138$ , therefore simple main effects were examined. The simple main effects for lifting method are presented first.

#### **Lifting method and power production**

For the jump method of the hang clean, the difference in power production among the four intensities was not statistically significant,  $F(3, 57) = .827$   $p = .442$ , partial  $\eta^2 = .042$ .

For the contact method, power production was significantly different between the four intensities,  $F(3, 57) = 11.930$ ,  $p < .05$ , partial  $\eta^2 = .386$ . Post hoc analyses with a Bonferroni

adjustment indicated that power production increased significantly from 50% 1RM to 80% 1RM. As shown in Figure 2, power production was significantly higher at 80% 1RM than 50% 1RM ( $M = 411.590$ , 95% CI [686.081, 137.099],  $p < .05$ ). Power production was also significantly greater at 70% 1RM than 50% 1RM ( $M = 350.967$ , 95% CI [172.372, 529.563],  $p < .05$ ).

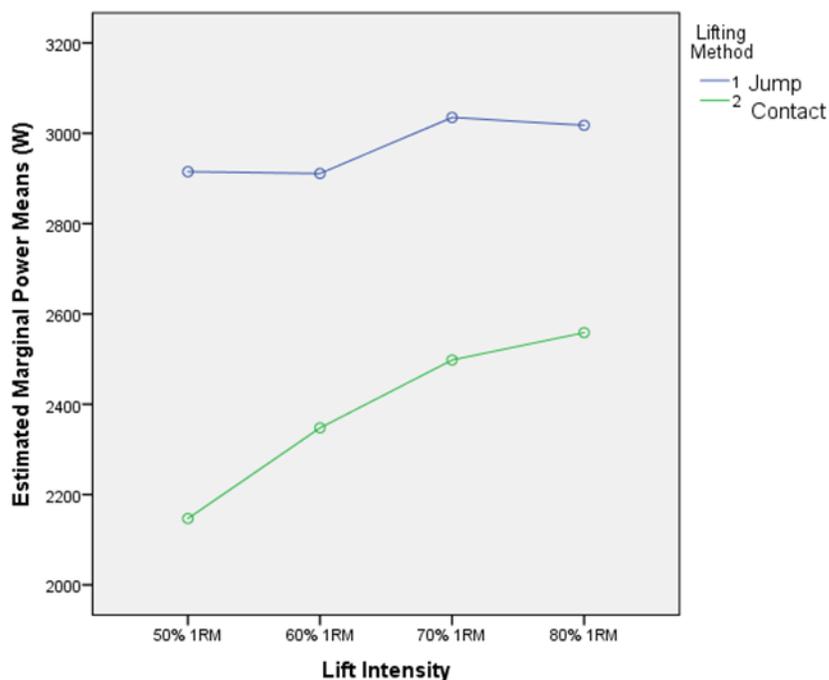


Figure 2. Mean Peak Power at Each Intensity for Both Lifting Methods.

### Lifting intensity and power production

Examining power production at different intensities regardless of lifting method, 70% 1RM was the only intensity to be significantly greater than another intensity. As shown in Table 2, power production at 70% 1RM was significantly greater than power production at 50% 1RM ( $M = 235.534$ ), 95% CI [12.005, 459.063],  $p < .05$ ).

Table 2

*Comparisons of Mean Difference in Peak Power by Intensity*

Lift Intensity		<i>M</i>	<i>SE</i>	<i>p</i>	95% CI	
					<i>LL</i>	<i>UL</i>
50% 1RM	60% 1RM	-98.3	56.3	.583	-264.1	67.5
	70% 1RM	-235.5	75.9	.035	-459.1	-12.0
	80% 1RM	-257.2	100.0	.112	-551.6	37.1
60% 1RM	50% 1RM	98.3	56.3	.583	-67.5	264.1
	70% 1RM	-137.2	63.5	.262	-324.2	49.8
	80% 1RM	-158.9	79.0	.351	-391.4	73.6
70% 1RM	50% 1RM	235.5	75.9	.035	12.0	459.1
	60% 1RM	137.2	63.5	.262	-49.8	324.2
	80% 1RM	-21.7	45.8	1.000	-156.6	113.2
80% 1RM	50% 1RM	257.2	100.0	.112	-37.1	551.6
	60% 1RM	158.9	79.0	.351	-73.6	391.4
	70% 1RM	21.7	45.8	1.000	-113.2	156.6

Note. CI = confidence interval; LL = lower limit; UL = upper limit.

**Lifting method and lifting intensity and power production**

Separate analyses of the four lifting intensities produced similar results in that power production was significantly higher at each intensity while employing the jump method (Table 3):

At 50% 1RM,  $F(1, 19) = 37.071$ ,  $p < .05$ , partial  $\eta^2 = .661$ . Post hoc analyses with a Bonferroni adjustment indicated that power production was significantly higher while performing the hang clean with the jump method ( $M = 767.956$ ), 95% CI [503.964, 1031.948],  $p < .05$ .

At 60% 1RM,  $F(1, 19) = 29.849$ ,  $p < .05$ , partial  $\eta^2 = .611$ . A post hoc analyses with a Bonferroni adjustment showed that power production was significantly higher when utilizing the jump method ( $M = 563.378$ ), 95% CI [347.549, 779.208],  $p < .05$ .

Table 3

*Summary of Mean Peak Power by Method and Intensity*

		50% 1RM	60% 1RM	70% 1RM	80% 1RM
Jump	<i>M</i>	2915.0	2911.0	3035.1	3017.8
	<i>SD</i>	1158.4	1001.3	992.0	839.3
Contact	<i>M</i>	2147.0	2347.6	2498.0	2558.6
	<i>SD</i>	932.0	913.5	870.2	816.1

At 70% 1RM,  $F(1, 19) = 20.942$ ,  $p < .05$ , partial  $\eta^2 = .524$ . A Bonferroni adjusted post hoc analyses again indicated that power production was statistically higher when using the jump method ( $M = 537.090$ ), 95% CI [291.445, 782.735],  $p < .05$ .

At 80% 1RM,  $F(1, 19) = 26.817$ ,  $p < .05$ , partial  $\eta^2 = .585$ . A post hoc analysis with a Bonferroni adjustment once again revealed that power production was significantly higher when performing the hang clean with the jump method ( $M = 459.246$ ), 95% CI [273.630, 644.862],  $p < .05$ .

## CHAPTER 5

### Discussion and Conclusions

#### Summary

The purpose of this study was to determine the optimal combination of lifting method and load intensity for power production during the hang clean. The statistical analyses indicate that both lifting method and load intensity had a significant effect on power production, and while this effect is modest at 13.80%, further investigation revealed more conclusive answers.

When the data was examined by intensity, the benefit to power production by employing the jump method became apparent. Overall, jumping produced significantly more power than maintaining contact with a mean difference of 581.917 W. This result was replicated at each tested intensity, with the greatest benefit being at 50% 1RM, where the mean difference in power production was 767.956 W. Jumping at this intensity attributed a 66.10% increase in power production over maintaining contact. The next greatest difference in power production was at the 60% 1RM intensity, where the mean difference was 563.378 W, (61.10% attribution). This was followed by 80% 1RM, with a mean difference of 459.246 W (58.50% attribution), and finally, 70% 1RM, with a mean difference of 537.090 W, or a 52.40% increase in power that can be attributed to jumping.

With the benefit of utilizing the jump method to produce more power when performing the hang clean established, attention was turned to determining the optimal

intensity to coincide with this method. Further analysis revealed that jumping at 70% 1RM elicited the greatest mean power output at 3035.070 W. In conjunction with the finding of power production being significantly greater 70% 1RM than at 50% 1RM regardless of lifting method, jumping at 70% 1RM is the preferred combination of lifting method and intensity for power production during the hang clean.

## **Conclusion**

While jumping at 70% 1RM is the favorable combination of lifting method and intensity with regards to power production during the hang clean, based on the data a practical conclusion cannot be drawn as to which combination is optimal. Statistically, the differences in peak power output were significantly greater when jumping at each intensity, but that difference was an average of only 1.25%. Furthermore, the difference in mean peak power between the two methods was marginal at 1.24%, with the difference between the greatest mean peak power (Jump Method at 70% 1RM) and the lowest mean peak power (Contact Method at 50% 1RM) separated by only 1.41%. Jumping at 70% 1RM produced the greatest mean peak power output of the tested combinations, but that value was only 1.01% greater than jumping at 80% 1RM, which produced the second largest mean peak power output (Table 4). Since the majority of the testing population for this study would be considered novices with regards to experience performing the hang clean, the results should be interpreted with that in mind; to project the findings onto more experienced weightlifters would be erroneous. Due to the minimal differences found between peak power values among the tested combinations, outside the realm of elite level athletes, suggesting that one combination is superior over the others would be misleading.

Table 4

*Mean Peak Power of Each Tested Combination*

	<i>n</i>	<i>M</i>	<i>SD</i>
Jump Method at 50% 1RM	20	2915.0	1158.4
Jump Method at 60% 1RM	20	2911.0	1001.3
Jump Method at 70% 1RM	20	3035.1	992.0
Jump Method at 80% 1RM	20	3017.8	839.3
Contact Method at 50% 1RM	20	2147.0	932.0
Contact Method at 60% 1RM	20	2347.6	913.5
Contact Method at 70% 1RM	20	2498.0	870.2
Contact Method at 80% 1RM	20	2558.6	816.1

**Practical Applications**

The hang clean is a complex and explosive movement that should be taught in progressive and deliberate steps. Specifically, an athlete should be able to successfully perform the contact method of the hang clean safely and consistently before being taught the jump method. The results of this study have shown that while a typical athlete is progressing through his or her learning and strength curves, there is no significant benefit of using one combination over the other. However, that does not mean the results are without merit because they can be applied to the majority of the population who perform the hang clean as part of a regular strength training program.

The greatest benefit will be realized by beginners and those athletes whose chosen sports do not require large bursts of power. For example, a basketball player requires the strength and power to be able to jump repeatedly throughout a contest, but does not require the same power output as a football player making a tackle. By being able to train at a lower intensity, the basketball player's training sessions can be more sport-specific in that he or

she can perform more repetitions per set with only a marginal difference in peak power produced. Similarly, a beginner would not be prescribed heavy intensities as part of his or her training program but could still realize similar gains in power by training at lighter intensities.

The results of this study can also be applied to scenarios of athletes recovering from an injury. If, for example, a football player was recovering from an ankle injury, he would be limited as to how much weight he would be able to lift during rehabilitation. While this athlete may normally train at 70% to 80% 1RM to maximize his power output, he can now train at 50% to 60% 1RM with minimal detriment to his power production. The results of this study may not have been able to definitively answer the original question, but they have generated knowledge that can be applied to the vast majority of the population who perform the hang clean as part of their regular strength training program.

### **Recommendations**

The participants of this study represented a broad spectrum of experience and athletic backgrounds so the results of this study should not be considered an absolute guideline for all athletes. The results would best be applied to those who are learning the hang clean, athletes who need to train for repetitive bursts of power, and those recovering from an injury. For sports that require infrequent expenditures of maximal power, such as football, it is recommended that a separate study be conducted with a testing population sampled from the sport to which the results will be applied. In the case of football, due to the inherent specialization of the sport, participants should represent each position to account for the differences in strength and body composition. An ideal study of this kind would have separate populations for each position group in order to attain the most position-specific

results. In either case, if this study were to be replicated, the researchers should be sure to randomize the lifting methods. The lack of random selection of the lifting methods in this study was an oversight, however it is not believed to have had a significant effect on the results.

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**APPENDICES**

APPENDIX A

IRB APPROVAL

# MEMORANDUM

To: Thomas Murray  
 Jeffrey Bauer

From: Irena Vincent, Primary reviewer on behalf of Institutional Review Board

Date: 10/2/12

RE: Institutional Review Board Approval

In accordance with SUNY Cortland's procedures for human research participant protections, the requested amendment to protocol referenced below has been approved for a period of one year:

**Title of the study:** Determining the Optimal Combination of Lifting Method and Load for Power Production  
 During the Hang Clean

<b>Level of review:</b> Expedited	<b>Protocol number:</b> 121303
<b>Project start date:</b> Upon IRB approval	<b>Approval expiration date*:</b> 10/1/13

\* **Note:** *Please include the protocol expiration date to the bottom of your consent form and recruitment materials.* For more information about continuation policies and procedures, visit [www.cortland.edu/irb/Applications/continuations.html](http://www.cortland.edu/irb/Applications/continuations.html) The federal Office for Research Protections (OHRP) emphasizes that investigators play a crucial role in protecting the rights and welfare of human subjects and are responsible for carrying out sound ethical research consistent with research plans approved by an IRB. Along with meeting the specific requirements of a particular research study, investigators are responsible for ongoing requirements in the conduct of approved research that include, in summary:

- obtaining and documenting informed consent from the participants and/or from a legally authorized representative prior to the individuals' participation in the research, unless these requirements have been waived by the IRB;
- obtaining prior approval from the IRB for any modifications of (or additions to) the previously approved research; this includes modifications to advertisements and other recruitment materials, changes to the informed consent or child assent, the study design and procedures, addition of research staff or student assistants, etc. (except those alterations necessary to eliminate apparent immediate hazards to subjects, which are then to be reported by email to [irb@cortland.edu](mailto:irb@cortland.edu) within three days);
- providing to the IRB prompt reports of any unanticipated problems involving risks to subjects or others;
- following the principles outlined in the Belmont Report, OHRP Policies and Procedures (Title 45, Part 46, Protection of Human Subjects), the SUNY Cortland College Handbook, and SUNY Cortland's IRB Policies and Procedures Manual;
- notifying the IRB of continued research under the approved protocol to keep the records active; and,
- maintaining records as required by the HHS regulations and NYS State law, for at least three years after completion of the study.

In the event that questions or concerns arise about research at SUNY Cortland, please contact the IRB by email [irb@cortland.edu](mailto:irb@cortland.edu) or by telephone at (607)753-2511. You may also contact a member of the IRB who possesses expertise in your discipline or methodology, visit <http://www.cortland.edu/irb/members.html> to obtain a current list of IRB members.

Sincerely,

*Irena Vincent*

Irena Vincent, Primary reviewer on behalf of  
Institutional Review Board  
SUNY Cortland

APPENDIX B  
INFORMED CONSENT

**PURPOSE:** To determine which combination of lifting method and load produces the most power during the hang clean.

**DESIGN:** You will perform four (4) sets of three (3) repetitions of the hang clean for each of two (2) lifting methods. The first method requires that you maintain constant contact with the ground while performing the lift. The second method requires that you jump during the pull phase of the lift and become airborne. Sets of three (3) will be performed using each method at 50%, 60%, 70%, and 80% of your one-repetition maximum for a total of eight (8) sets.

**PARTICIPATION:** By signing this informed consent form, you agree to be a participant in this study. You will be asked to participate in three separate data collecting sessions, each of which will last approximately twenty (20) minutes. The first session will be to determine your one-repetition maximum for the hang clean, while the second and third sessions will be used to measure your power production during different combinations of lifting methods and loads.

**RISKS:** I do not anticipate any risks to you participating in this study other than those encountered in daily life.

**BENEFITS:** Information from this study will be used in the prescription of strength training programs for varsity athletes at SUNY Cortland. Your participation in this study is voluntary. You may discontinue your participation at any point and have the right to refuse to perform any of the lifts within this study without penalty. You are allowed to ask questions about the study both before agreeing to participate and at any point

during the study. Your information will remain confidential as it will not be released; it will only be available to myself and the faculty and students assigned to this study. All data from this study will be kept in my possession for a period of three (3) years, after which it will be destroyed. Audio and visual recordings will be made of each data collection session but will be destroyed after the transcription of data has occurred. To maintain your anonymity, I will be the only one with access to these recordings. Upon request, you may receive a copy of this signed and dated informed consent form.

**RESEARCHER CONTACT INFORMATION:**

Thomas Murray

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I, \_\_\_\_\_ agree to participate in the study described within this informed consent form. Furthermore, I am aware of the risks involved and wish to participate of my own free will.

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

*Protocol Expiration Date: 10/1/13*