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The Effects of Lifting Straps on Force Applied During the Power Clean

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Abstract Lifting straps (LS) are often used by individuals to aid in the execution of the power clean (PC) as they aid in the hand coupling with the lifting bar. **PURPOSE:** This study analyzed the PC exercise in regards to ground reaction force (GRF), rate of force development (RFD) and 1RM, both with and without lifting LS. **METHODS:** There were 13 participants in this study comprised of male high school basketball players with an age range of 13-17. All participants have had a minimum of one year of proper weight lifting training provided by a certified personal trainer, and experienced Olympic style weight lifter. The study used a repeated measures cross over study design where the participants performed two sets of two reps of the PC, both with and without LS. The athletes performed a dynamic warm-up followed by progressive sets of the PC at low intensity (50% of their 1RM). Following the dynamic warm-up and PC progression sets the participants performed two sets of two repetitions with and without LS at an intensity of 70% 1RM while standing on a force plate. The peak vertical GRF (Newtons-N) and RFD (N/second) were assessed for second pull of the PC. The peak GRF and RFD were compared between conditions with paired t-tests. The force plate collected data at a sampling rate of 1000 hertz and the subsequent data was filtered at 100 hertz. **RESULTS:** The 1RM PC with no LS was significantly lower (72.7±15.9 kgs*) than the 1RM PC with LS (79.0±18.4 kgs). Peak vertical GRF was significantly lower for the LS conditions (1953.3±450.7 N*) compared to the no LS conditions (2004.0±443.7 N) ($p<0.05$). Peak vertical RFD was not significantly different between the LS conditions (16011.7±8301.5 N/sec) and no LS Conditions (16012.3±7341.5 N/sec) ($p>0.05$). **CONCLUSION:** Within the parameters of this study, the use of lifting LS did improve PC 1RM. However, LS did not improve the ability to generate greater vertical GRF or RFD. Coaches should work with their athletes on an individual basis to determine if the use of LS would be advantageous when performing the PC.

Keywords Olympic Lifts, Forceplate, Ground Reaction Force

1. Introduction

The power clean (PC) is an exercise that has a variety of advantages for any athlete. The PC uses a majority of the muscles in the lifter's body. The PC is performed standing, is performed explosively, and also generates extensive power [7]. All of those attributes are thought to positively transfer directly into an athlete's performance [7]. The PC is effective because it engages the triple extension movement that includes the hip, knee, and ankle joints. The triple extension movement is the same pattern found in athletic movements such as tackling, starting a sprint, or jumping [30]. The PC engages the same muscles and joints as in a variety of sports movements. As example, when an athlete jumps, these same joints have to be fully extended, in other words, triple extension [30].

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The triple extension movement in the PC is essential because it enhances the development of power by moving heavy loads at high speeds The PC also strengthens the posterior chain muscles of the spinal erectors, glutes, hamstrings, and calves (backside muscles). This is important because those muscles are activating in things like sprinting, and explosively coming out of the starting blocks [30].

The PC may be one of the most versatile Olympic lifts. It is also one of the most accessible, which makes it even more appealing. Taking the time and effort to learn the correct movement and application will provide a positive impact on body composition, strength, and power [21].

One obvious benefit of the PC that should be noted is its ability to train muscular power. Power is a combination of strength and speed and the PC lift promotes quick muscle contractions needed for explosive sports such as football, wrestling, track, rugby, and many others, possibly better than any other lift or exercise movement. Because the PC relies on several joints and muscles, and works in several points of motion, it helps to train movements, rather than isolating muscles. This training will transfer into the sport. The PC has several progressions leading up to the completion of the lift and is described in detail elsewhere [22].

Explosive Olympic lifts involve high force and high velocity movements [17]. The vast majority of sports require an athlete to exhibit explosive power into play to help reach their full potential. Power is simply the body's ability to produce the greatest amount of force in as little time as possible [24]. Physical characteristics of strength and speed are becoming more prevalent in sports, and Olympic lifts have a direct impact on those.

The PC definitely falls into the category of lifts using high velocity and high power. The repetition and practice of this lift can enhance athletic performance by training the muscular movements necessary for the sport. As mentioned above, the PC utilizes the triple extension and explosiveness. It transfers directly into a variety of sports movements. The PC movements are one of the best measurements of total body strength and power [14].

When referring to Olympic lifts and their derivatives, the term variation may be used in reference to the lifts because some athletes may not be able to attain the deep squat position required of the snatch as well as the clean and jerk. They may alter or modify the lift movement, while still accomplishing similar movements and activating similar muscle groups. While the Olympic lifts do not exactly simulate many specific sport skills when it comes to movements such as throwing, running, and/or catching, the Olympic derivatives do develop the particular adaptation and transfer of explosive power. Power is directly linked to force and explosiveness [28]. That being said, although the actual lift movements may not mimic the sports movements, they do mimic the stance. The "universal athletic stance" is similar to the static posture used when beginning most of these lifts. This involves balance and weight distribution, and essentially a "ready position".

Athletes working towards power and strength enhancement can be affected by Olympic lift variations. Athletic success can directly be determined by the ability to generate high power outputs. Explosive exercises typically generate power, force, and acceleration, which result in having maximal or near maximal movement velocities of given movements [17].

The Olympic lifts and their variations require power and strength, especially in the lower body. A training method involving the use of weights, resistance, and these lifts seems to be much more beneficial and efficient than one using no weights, such as vertical jump training, endurance, or body weight training [29]. Although there is still less research and data when it comes to younger athletes, the utilization of Olympic lifts and variations in high school strength programs is growing more common. Two specific surveys of high school coaches highlighted that Olympic style lifts and variations thereof were the most essential exercises these coaches recommended for athletes [14, 31].

Variations of the PC, using different starting points are commonly incorporated into strength and conditioning programs. The movements in the lift do imitate certain specific sports movements, while using explosive power [10].

As previously stated, power is defined as "the ability for the body to produce the greatest amount of force in as little time as possible" [24]. Force can be described as "strength or energy exerted or brought to bear" [24].

Power can be illustrated as the product of force and velocity. In sports that require high force development in a short amount of time, muscular power is a key determinant. Training power and force applied could have a direct influence on power output in specific sports movements. Because of the fact that weight lifting movements involve large muscle mass, multi-joint movements, and fast movement velocity, it can be highly specific and effective to sports performance. With that in mind, one can assume that the combination of muscle building and high velocity motions can produce optimal results in an athletes' abilities. In short, force and strength lead to a powerful athlete [9].

In a study conducted with 19 male collegiate rugby players, peak power output was determined during the PC performed at a variety of loads in a randomly counterbalanced order [9]. All participants had regularly been involved in a strength and conditioning program as preparation for their sport. They had all previously conducted technique training sessions and were aware of the protocol and expectations. This would lead to reliability and validity within the study. In general, as the load increased, the peak RFD increased as well. The greatest peak RFD occurred at 70%. The primary finding shows that peak power output was maximized at 70% in PC. The force increased as the load increased and reached its optimal progression at 80%. More research will need to be done to determine how the training correlates to the performance, depending on the sport which will address what movements, power, or force are necessary [9].

As mentioned before, muscular power is a key aspect of athletic performance. This is especially pertinent in sports that require high force generation in a short amount of time. Power is the product of force. Therefore, training that is aimed at improving power is essential for athletes. Power output is maximized at submaximal loads. Power training should be accompanied by maximal effort to produce force as quickly as possible. This will in turn maximize power output [20].

The peak rate of force development (PRFD) is traditionally higher in male athletes who use explosive exercises of various intensities. Slower RFDs are usually observed in athletes who do not display as much explosiveness, such as endurance athletes [16]. Force and explosiveness are not a necessity to those types of athletes. There is minimal data and research on the elements and consistencies of PRFD in regards to female athletes [16].

Lifting straps (LS) help the athlete in holding/gripping the barbell, especially under high loads or high volumes of weight [19]. The LS are approximately 1-1.5" wide and 1-1.5' long. The LS are typically a material comprised of leather, canvas, or nylon. Figure 1 illustrates the use of the LS aiding in grip. The purpose of the LS would be to allow the lifter to focus on the actual pull or lift portion of the exercise, and not the grip [6]. LS help the athlete in holding/gripping the barbell, especially under high loads or high volumes of weight [19]. Often times when fatigue comes into play, form and grip strength can be sacrificed. LS can become a beneficial asset in these circumstances. It is not recommended that beginning lifters use LS, as it can falsify strength or ability, even tricking the nervous system [6].

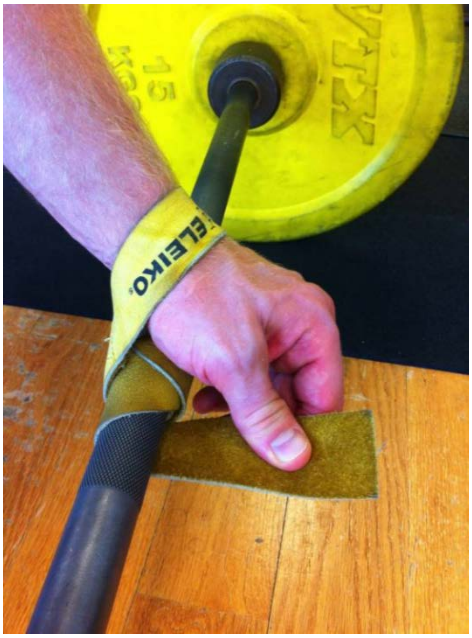

Figure 1. Use of lifting straps to assist in holding the bar

Some coaches strongly believe in using them, while some simply opt out. Some athletes prefer the way they feel and enhance their lifting ability, while some simply choose to lift without them. It also depends on the goals. It is thought that if the goal is to lift more, and be more explosive, LS may be beneficial enabling the lifter to focus on the lift itself, rather than gripping the bar. If the goals involve grip strengthening, the use of LS may impede that goal.

One study focused on the effects of LS on PC performance [19]. The study addressed peak velocity, force, and power. The study conducted used five male rugby players performing two sets of two repetitions of PC, both with and without LS. An optical encoder was mounted to the barbell. This tool obtained the peak velocity of the actual barbell, as well as the force/power applied to the barbell. The researchers took the highest recorded value of the four total trials in each condition to make the comparisons. The results showed that four out of the five participants showed greater peak velocity, force, and power with the LS. One player did not show a difference between the two conditions. Based on this study, one can conclude that the use of LS is beneficial for athletes wishing to enhance velocity, force, and power during the PC [19].

As mentioned above, the LS are presumably beneficial in assisting in grip and make it easier to hold onto the bar. This provides lifters the opportunity to focus on the actual lift and technique, rather than their grip. At the same time, that may be the exact reason a coach would choose not to use LS. If the athlete uses LS to aide in grip, they may not be taking the opportunity to strengthen their grip by the nature of gripping the bar unassisted. Many sports require grip strength, so coaches tend to prefer grip strength in part of the training. Also, if an athlete is training for competitions, it will not benefit them to use LS, as they will not be able to use them in the competitions. Lifters have to have a clear understanding of goals so an efficient lifting protocol is utilized.

The purpose of this study was to determine if using LS would allow an individual to apply more force at a greater rate during the execution of the PC as measured by a force plate. Further, it was on interest to determine if the use of LS could improve PC one repetition maximum ability.

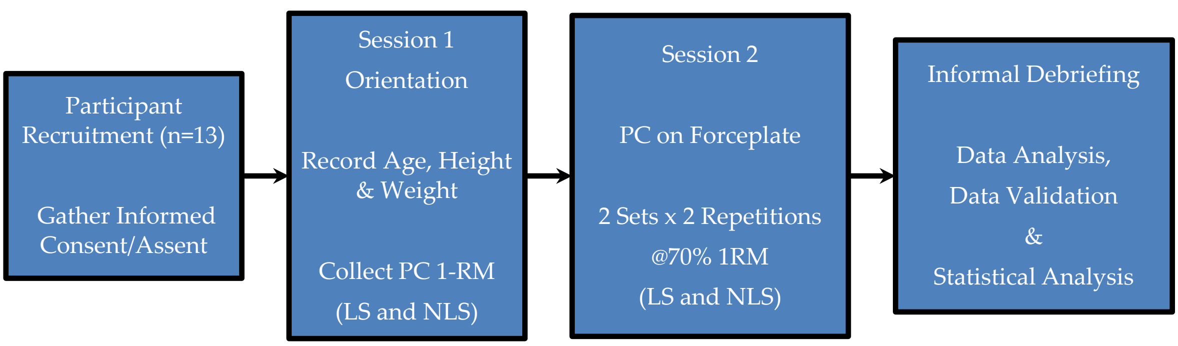

Figure 2. Study time line of events. PC-power clean; LS-lifting straps; NLS-no lifting straps; Forceplate-PCs performed on the forceplate

2. Methods

2.1. Participants

There were 13 participants in this study. The group was composed of male high school basketball players with an age range of 13-17. All participants had a minimum of one year of proper weight lifting training provided by a certified personal trainer, and experienced Olympic style weight lifter. All of the participants were at a good physical fitness level. They were considered well prepared for the study protocol activities because sufficient training and practice had taken place, both with and without the LS.

Prior to engaging in the study with the student athletes, permission to conduct the study was obtained from the Institutional Review Board. Written permission was obtained from each of the participants and their parents (due to the fact that they were minors). The principal investigator of the study was present at all times.

2.2. Instruments and Apparatus

The study was conducted at two locations: the Duchesne High School Weight room (Duchesne, Utah) and Southern Utah University in the "Lab" of the Kinesiology and Outdoor Recreation Department (Cedar City, Utah). The weight lifting equipment, including barbells, and necessary bumper plates was were housed in both locations. Although the LS were available for use at the University, the athletes also had the option to supply their own that they used regularly and as described previously.

The force plate used in the current study was also located in the Lab. The make/model of the plate used was the Bertec jump plate (FP6090-15-1000), Bertec Corp., Columbus, OH. The Bertec jump plate provides a precise biomechanical measure of jump force, power, and height during a vertical jump or liftoff. The 24" X 35" X 2" (width X length X height) force plate is comprised of strain-gage load transducers that measure six components: three orthogonal forces and the moments of each axis. The force plate was firmly positioned on the ground.

Each PC repetition was performed with the athletes standing on a force plate. The force plate collected data as a sampling rate of 1000 hertz and the subsequent data was filtered as 100 hertz generating a force time curve (FTC). The FTC was later analyzed to determine the peak vertical ground reaction force (GRF or Fz-Newtons) and rate of force development (RFD) during the second pull of the PC. Previous research has indicated that the second pull during the PC is where the greatest GRF and power output occurs [13, 15, 27]. RFD was figured by dividing the difference in consecutive Fz readings by the time interval (.001 seconds) (9). The GRF was determined by analyzing the corresponding force time curve and identifying the maximum GRF value.

A previous study by Comfort, Fletcher and McMahon [9] indicates that Intraclass correlation coefficient (ICCs) for measures of GRF and RFD while performing PCs (@ 70% 1RM) on a force plate were ICC_{GRF}=0.957 and ICC_{RFD}=0.912, both considered high reliability [4].

2.3. Procedures

2.3.1. Assessment

For approximately one month before the Lab assessments, the athletes had ample opportunity to practice the PC both with, and without LS. They took this time to work on form and comfort level of the PC, while being observed by the team coach (i.e. principal investigator). This group of participants was more experienced using LS than without. Because of this, they needed to practice performing the lift without the LS. In order to ensure that the results of the study were valid, it was important that the athletes were very familiar with performing the PC under both conditions. The assessment period of the study spanned two weeks. Each participant established their one repetition maximum (1RM) with LS and without LS (NLS) within one week of the Lab assessments. The 1RM PCs were established as previously described [3]. The NSCA recognizes 1-RM measures as a reliable assessment of muscular strength [3]. The PC 1RM were recorded for direct comparison between strapped conditions and to calculate the load to be lifted during the Lab assessments (i.e. 70% 1RM). The PC 1RMs were collected at the Duchesne High School Weight room and the Lab assessments were recorded at Southern Utah University in the Human Performance Lab of the Kinesiology and Outdoor Recreation Department (Lab).

One week following the PC 1RM assessments the participants met at the Lab. There were two conditions for the study; PC with LS, and PC without LS. Prior to conducting the assessed PC sets the athletes engaged in a dynamic warm-up. The dynamic warm-up included: one-minute jump rope, walking lunges (approximately 30 feet down and back x 2). Following the lunges, the participants performed up to four repetitions of progressive sets of warm-up PC at low intensity (50% of their 1RM). After the progressive sets of PC, participants were allowed three-five minutes before their first assessed set of PC on the forceplate.

The participants performed two sets of two reps, of PC both with and without LS at an intensity of 70% 1RM. Previous research [9] has indicated that maximal power out occurs at a load of 70% 1RM while performing the PC. The sets of PC were conducted while the participants stood on the force plate. The 13 participants were divided into two groups (n=6 and n=7). A repeated measures cross over design was utilized for this study. Meaning that half of the participants performed the PC with LS first, and the other half performed without LS. Then, each group switched. The athletes were paired up so that two perform the entire process together taking turns and using similar amounts of rest times. After each set, the athletes took a minimum of two minutes, and a maximum of five minutes of rest. Providing ample time ensures the lifter is ready, but placing a cap on it kept the athletes consistent with one another, as well as making the study flow smoothly. As soon as two subjects completed the process, the next two would go until the entire group made it through. These steps minimized wait time for each athlete, as well as keeping the process consistent.

2.3.2. Statistical Analysis

There was one independent variable in this study with two levels (the conditions of LS and NLS). The dependent variables (DV) were: 1RM, vertical peak and ground reaction force (GRF) and vertical ground reaction force rate of development (RFD). The PC 1RM were compared between strapped conditions with paired t-tests. The maximum value of the GRF, and RFD (across all 4 attempts) as assessed during the second pull of the PC were compared between conditions (LS vs. no LS) with a paired t-tests (alpha<0.05). Likewise, an average of the DVs was calculated for each condition, where by the maximum vertical GRF and RFD assessed for each set was averaged. The average DVs were compared between conditions (LS vs. no LS) with a paired t-tests (alpha<0.05). Statistical calculations and data management were conducted with Microsoft Excel 2013. The assembled spread sheet of test data was peer reviewed for errors prior to analysis as previously suggested [1].

3. Results

All thirteen participants completed the study procedures, without complication. The participant's demographics are in Table 1. The PC 1RM were significantly greater for the LS condition compared to the NLS condition (p<0.05) with an effect size difference of 0.40 standard deviations.

Table 1. Study Participant Descriptive Data

Age (yrs)	Height (cms)	Mass (kgs)	1-RM LS	1-RM NLS
15.3	177.0	83.3± 12.7	79.0±18.4	72.7±15.9*

Participant (n=13) means and standard deviations for descriptive information. 1-RM one repetition maximums (kilograms). LS-lifting straps. 1-RM NLS significantly lower than 1-RM LS (p<0.05).

The maximum GRF for participants without the use of LS was 2004.0±443.7 (Newtons) compared to 1953.3±450.7 (Newtons) with the use of LS. The average GRF for participants without the use of LS was 1945.6±443.8 (Newtons) compared to 1889.5±451.4 (Newtons) with the use of LS (Table 2). The average GRF and the maximum GRF were significantly lower with the use of LS compared to no LS (p<0.05).

The maximum RFD for participants without the use of LS was 16012.3±7341.5 (Newtons/sec) compared to 16011.7±8301.5 (Newtons/sec) with the use of LS (Table 3). The average RFD for participants without the use of LS was 13,948.8±6516.3 (Newtons/sec) compared to 13,563.63±6968.4 (Newtons/sec) with the use of LS. The average RFD and the maximum RFD showed no significant differences between no LS and LS conditions (p>0.05).

Table 2. Vertical Ground Reaction Force

Vertical GRF			
Maximum		Average	
Straps	No Straps	Straps	No Straps
1953.3±450.7*	2004.0±443.7	1889.5± 451.4*	1945.6± 443.8

Means and standard deviations for paired trials of PC measuring Ground Reaction Force (GRF-Newtons). GRF LS significantly less than NLS (p<0.05).

Table 3. Vertical Rate of Force Development

Vertical RFD			
Maximum		Average	
Straps	No Straps	Straps	No Straps
16011.7± 8301.5	16012.3± 7341.5	13563.3± 6968.4	13948.8± 6516.3

Means and standard deviations for paired trials of PC measuring Rate of Force Development (RFD). (Newtons/sec)

4. Discussion

The purpose of the study was to determine if the use of LS could improve one's ability to couple with the weight bar leading to improved PC 1RM ability as well leading to higher GRFs and RFD when performing the PC at 70% of 1RM. It was hypothesized that the use of LS would allow an individual to have a more secure coupling with the bar which in turn would allow for a greater transfer of muscular strength and power to the weight bar, hence leading to beneficial changes in the aforementioned variables. The results of the study were mixed.

The 1RM PC were significantly greater when the participants used the LS. The NLS PC 1RM were 72.7±15.9 kgs which is approximately 30 percentile for boys who play North American football [18]. Whereas LS PC 1RM were 79.0±18.4 kgs which is approximately 50 percentile for boys who play North American football [18]. The difference in wearing LS equates to approximately an 8.7% on average improvement with an effect size of 0.4 standard deviations. Twelve of the 13 participants improved the 1RM PC with the use of LS (increase range 2.2-16.0 kgs). In our opinion, the use of LS should provide the ability to chronically handle an elevated load while performing the PC, which in turn should lead to superior muscular adaptations over time.

The GRF data assessed in the current study compares favorably with the GRFs reported in prior studies examining the second pull of the PC [8, 9, 19]. Hori et al. [19] reported GRFs averaging 1948.0±130.0 Newtons when performing the PC at a bar load of 140 kgs. The participants in the Hori et al. study were well trained professional Rugby Union players and it was not reported as to what % of a 1RM the 140 kg loaded bar was for the participants. Two studies by Comfort and colleagues [8, 9] reported GRFs of 2,306.2±240.5 and 1,921.2±345.2 Newtons while conducting the PC on a forceplate at loads of 60% and 70% 1RM respectively. The participants in the Comfort studies were collegiate athletes and elite Rugby players all with more training experience and physical maturity then the participants in the current study. When examining the GRF data, the use of LS on average reduced the peak vertical GRF during the second pull of the PC at 70% 1RM which is contrary to our hypothesis. Further, the results of the current study are in direct contrast the results of the Hori et al study that demonstrated that LS increased GRF during the PC with a bar load of 140 kg. Our expectations were that if LS increased PC 1RM then LS should increase GRF while performing the PC at loads of 70% 1RM. As such, the results with in our study seem to be conflicting. One possible explanation is that LS are only effective for near maximal loads and/or the later repetitions in a set, a time when the coupling of the hand with the weighted bar starts to be compromised. Another explanation might be that if the LS were not tightly worn (i.e. a bit of slack) during the 70% 1RM sets then a dampening effect of the maximal GRF scores could have occurred. Another thought on the matter. It is possible that the use of LS is more important for coupling with the bar during the initial or first pull of the PC. If so, a stronger initial pull would lead to a more advantageous scenario to engage the second pull during a maximal attempt PC, hence a greater 1RM. Since griping the bar loaded at 70% 1RM may not be challenging, the addition of LS may provide no added benefit during initial pull, and hence, the second pull of the PC. Conversely, it is possible that using the LS led to the participants not having to pull as hard to complete the sets at 70% 1RM, and hence resulting in lower GRFs compared to the NLS sets.

The RFD data assessed in the current study (NLS 16012.3± 7341.5 Newtons/Sec) is much higher than RFD reported in the Comfort et al. studies [8, 9] when examining the second pull of the PC. The studies by Comfort and colleagues [8, 9] reported RFD of 8,839.7±2,940.4 and 10,741.9±4,291.0 (Newtons/sec) while conducting the PC on a forceplate at loads of 60% and 70% 1RM respectively. We suspect the difference RFD magnitude between the current study and the Comfort studies has to do with how the RFDs were arrived at. In the current study, the Fz time signal from the forceplate was filtered at 100 hertz, whereas the Comfort studies smoothed the Fz time signal with a moving average frame of 400 milliseconds. As such, we feel our reported RFD maximum values are a more accurate representation of the true maximum RFD score. There was no difference in the RFD scores between the LS and NLS conditions. Again, our expectations were that if LS increased the PC 1RM, then LS should increase RFD while performing the PC at loads of 70% 1RM. The results with in our study seem to be conflicting. There is a relationship between strength and power [23]. In the case of our study, the 1RM PC is an absolute measure of muscular strength and power, whereas, the PC at 70% 1RM is more reflective of muscular power. The Pearson correlation coefficient between the NLS 1RM and NLS RFD in the current study is r=0.31. In other words, there is a very poor relationship between strength and power in this study group. It is possible that the training status of these young athletes (≈15 years old) has not reached the point where newly acquired strength has transferred to the attributes of speed and muscular power. It would be of interest to repeat this study with the same participants when they reach the age of 18 years. At that point in time, the participants would have had several more years of formal resistance training experience, physical maturity, and presumably a time when the relationship between strength and power would be much greater than at age 15 years.

When coaches are working with athletes there should always be an individualized approach tailored to the needs of the athletes. For example two studies [2, 25] demonstrated that different Olympic derivatives had an equal positive impact on measures of speed, strength, and power. Knowing that the varying lifting derivatives provided similar improvements in the aforementioned variables, one can provide variability within resistance training protocol suited to the individual. Likewise, LS have been demonstrated to improve PC 1RM ability. However, some lifters with large hands may have no issue grasping the bar regardless of the load. Meanwhile, athletes with smaller hands may experience less ability to grasp the bar during high intensity load sets, or the latter repetitions in a high repetition set. Generally, speaking, men have greater grip strength then woman [11, 12, 26] and women have smaller hands than men. With that said, LS maybe very advantageous particularly for female athletes in order to facilitate the ability to grasp the bar during challenging sets of PC.

5. Conclusions

This study determined that LS facilitated a meaningful increase in PC 1RM ability. It is reasonable to think that chronically engaging in resistance training with greater PC loads will lead to superior muscular adaptations over time. The use of LS however did not improve attributes of GRF or RFD. It is our opinion, that LS did not aid in improving GRF or RFD is this study group was likely due to the lack of maturity of the young athletes and the poor relationship exhibited between strength and power in this cohort. We suggest that coaches should work individually with athletes to determine if and when LS are appropriate.

REFERENCES

[1] Al Tarawneh, G., & Thorne, S. (2017). A pilot study exploring spreadsheet risk in scientific research. arXiv preprint arXiv: 1703.09785.

[2] Ayers, J., DeBeliso, M., Sevene, T., & Adams, K.J. (2016). Effects of the hang clean and the hang snatch in women athletes. *Biology of Sport, 33*(3), 251-256.

[3] Baechle, T.R., Earle, R.W., & Ratamess, N.A. (2008). Essentials of strength and training and conditioning (3rd Ed.). Champaign, IL: Human Kinetics.

[4] Baumgartner, T.A., Jackson, A.S., Mahar, M.T., & Rowe,

D.A. (2007). Measurements for evaluation in physical education and exercise science (8th Ed.). New York, NY: McGraw Hill.

[5] Blanchard, J., Berning, J., Adams, K.J., & DeBeliso, M. (2016). Effects of the trap bar deadlift and leg press on adolescent male strength, power and speed. Journal of *Physical Education Research*, *3*(2), 11-22.

[6] Chasey, K. (n.d.). Weight Lifting Straps: What They Are. breakingmuscle.com. Retrieved March 26, 2017, from https:/breakingmuscle.com/weight-liftingstraps-what-they-are-when-and-why-to-use-them.

[7] Cissik, J. (n.d.). PC improving athletic performance |an exercise blog for coaches and athletes. Retrieved December 5, 2013, from http://www.cssik.com/blog/tag/power-clean/.

[8] Comfort, P., Allen, M., & Graham-Smith, P. (2011). Comparisons of peak ground reaction force and rate of force development during variations of the power clean. *The Journal of Strength & Conditioning Research*, *25*(5), 1235-1239.

[9] Comfort, P., Fletcher, C., & McMahon, J.J. (2012). Determination of optimal loading during the power clean, in collegiate athletes. *Journal of Strength and Conditioning Research, 26*(11), 2970-2974.

[10] Comfort, P., McMahon, J.J., & Fletcher, C. (2013). No kinetic differences during variations of the power clean in inexperienced female collegiate athletes. *Journal of Strength and Conditioning Research, 27*(2), 363-368.

[11] DeBeliso, M., Boham, M., Harris, C., Carson, C., Berning, J.M., Sevene, T.G., & Adams, K.J. (2015). Grip and body strength measures in the mature adult: A brief report. *International Journal of Science and Engineering* Investigations, 4(37), 83-86.

[12] DeBeliso, M., Boham, M., Harris, C., Carson, C., Berning, J.M., Sevene, T.G., Adams, K.J., & Climstein, M. (2015). Grip strength and functional measures in the mature adult: Brief report II. *International Journal of Science and Engineering Investigations*, *4*(39), 1-4.

[13] Enoka, R. (1979). The pull in Olympic weightlifting. *Medicine Science and Sports, 11*, 131–137.

[14] Faigenbaum, A. D., McFarland, J.E., Herman, R. E., Naclerio, F., Ratamess, N.A., Kang, J., & Myer, G.D. (2012). Reliability of the one-repetition-maximum power clean test in adolescent athletes. *Journal of Strength and Conditioning Research, 26*(2), 432-437.

[15] Ha¨kkinen, K, Kauhanen, H, and Komi, P. (1984). Biomechanical changes in the Olympic weightlifting technique of the snatch and the clean and jerk from submaximal to maximal loads. *Scandinavian Journal of Sports Science, 6*, 57–66.

[16] Haff, G.G., Carlock, J.M., Hartman, M.J., Kilgore, J.L., Kawamori, N., Jackson, J.R., . . . & Stone, M.H. (2005). Force-time curve characteristics of dynamic and isometric muscle actions of elite women Olympic weightlifters. *Journal of Strength and Conditioning Research, 19*(4), 741-748.

[17] Haff, G.G., Whitley, A., & Potteiger, J. A. (2001). A brief review: explosive exercises and sports performance. *Strength and Conditioning Journal*, *23*(3), 13.

[18] Hoffman, J. (2006). *Norms for fitness, performance, and health*. Human Kinetics, Champaign, IL, USA.

[19] Hori, N., Appleby, B.B., Andrews, W.A., & Nosaka, K. (2010). The effect on lifting straps on peak velocity, force, and power during clean pull. *Journal of Australian Strength and Conditioning, 18*(2), 4-9.

[20] Kawamori, N., Crum, A.J., Blumert, P.A., Kulik, J.R., Childers, J.T., Wood, J.A., & Haff, G.G. (2005). Influence of different relative intensities on power output during the hang power clean: identification of the optimal load. *The Journal of Strength and Conditioning Research, 19*(3), 698.

[21] Moss, S. (n.d.). The many benefits of the power clean. Retrieved April 10, 2017, from https://upfitness.com/en/article_posts/bodybuilding/training/benefits-power-clean.

[22] Newton, H. (2002). Clean. *Explosive lifting for sports.* Champaign, IL: Human Kinetics.

[23] O'Shea, P. (2000). Quantum Strength Fitness II (Gaining the winning edge). Applied strength training & conditioning for winning performance, Patrick's Books, Corvallis, OR, USA.

[24] Painter, D. (n.d.). Olympic Weightlifting: Implementation and Progression. Retrieved July 2017. assets.ngin.com/attachments/document/0116/4860/Olympic_Weightlifting.pdf.

[25] Sanders, C., Sevene, T., Adams, K.J., & DeBeliso, M. (2017). A pilot comparison of the hang clean and hang snatch to the clean pull and snatch pull. *Journal of Athletic Enhancement*, *6*(5), 1-5.

[26] Sevene, T.G., Berning, J., Harris, C., Climstein, M., Adams, K.J., & DeBeliso, M. (2017). Hand grip strength and gender: allometric normalization in older adults and implications for the NIOSH lifting equation. *Journal of Lifestyle Medicine*, 7(2).

[27] Souzam, AL, Shimada, SD, & Koontz, A. (2002). Ground reaction forces during the power clean. *Journal of Strength and Conditioning Research*, *16*, 423–427.

[28] Sutton, B. (2017). The scientific rationale for incorporating Olympic weightlifting to enhance sports Performance. *National Academy of Sports Medicine*.

[29] Tricoli, V., Lamas, L., Carnevale, R., & Ugrinowitsch, C. (2005). Short-term effects on lower-body functional power development: weightlifting vs. vertical jump training programs. *The Journal of Strength and Conditioning Research, 19*(2), 433.

[30] Tucker, D.R. (2011). Teaching the Power Clean. Retrieved April 23, 2017, from https://www.elitefts.com/education/training/sports-performance/teaching-the-power-clean/.

[31] Weaver, K., & DeBeliso, M. (2015). Survey of Utah High School Football Strength and Conditioning Coaches. *Journal of Sports Science, 3*(3), 117-126.