THE INFLUENCE OF THE CLOSED GRIP, HOOK GRIP, AND LIFTING STRAPS ON KINETIC, KINEMATIC, AND QUALITATIVE PERFORMANCE VARIABLES OF THE POWER SNATCH

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TABLE OF CONTENTS

ABSTRACT

Weightlifters routinely utilize the hook grip (HG) or may use lifting straps (LS) when performing the various lifts in training. While weightlifting specific movements and their derivatives have been extensively researched and shown to provide beneficial adaptations towards a range of athletes, the influence that different grip-types have on the performance of these lifts is not yet fully elucidated. To date, no investigation has examined what influence the HG or LS has on the kinetic, kinematic, and qualitative performance variables of the power snatch (PS). Thus, the primary purpose of this thesis was to compare the kinetic, kinematic, and qualitative outcomes of the PS with and without the HG and LS compared to a closed grip (CG). It was hypothesized that the HG and LS would increase maximal lifting performance, and enable greater levels of force, and velocity to be generated compared to a standard CG method. It is also hypothesized that the HG and LS would enable an optimized bar-path when compared to the CG condition. Finally, it is hypothesized that participants' subjective ratings would largely reflect the positive kinetic and kinematic outcomes. Ten resistance-trained (male; n=6, female; n=5) individuals participated in this study. Before the formal testing procedures, a familiarisation took place where each participant completed a 1RM PS with the CG. Each participant then performed three additional 1RM testing sessions whereby the grip-type (HG, CG, or LS) were randomly assigned. A minimum of five and a maximum of ten days separated each standardised testing session. System (lifter + barbell) ground reaction force kinetics were recorded via a force platform, and dual linear position transducer system and bar-path kinematics were ascertained via two-dimensional (2D) motion capture. Each attempt was filmed directly from the side to measure the bar path. Following the 1RM, participants were required to fill out a short questionnaire based around grip security and thumb grip pain. No statistically significant differences were found between 1RM in any conditions between sex (p = 0.13, ηp^2 = .40). However, when adjusted for sex, females had a significantly higher 1RM using LS when compared to CG (p = 0.03, ηp^2 = .90). Peak force (PF) and barbell velocities were similar between conditions with no significant differences (p = >0.05, ηp^2 = .36). Qualitatively, LS provided significantly higher grip security off the floor (p = 0.02, ηp^2 = .60), and during the second pull phase of the PS (p = 0.01, ηp^2 = .71). Furthermore, the participants also reported feeling more powerful while using LS (p = 0.02, ηp^2 = .64), but there were no significant differences in how fast the participant felt catching the barbell (p = 0.06, ηp^2 = .51). These findings suggest that females may benefit by using LS when attempting to achieve a higher 1RM with the PS. Furthermore, novice athletes or those that lack confidence during certain phases of a lift may benefit by using LS.

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Signed…………………………………….

Date…11/05/2020…………………………………

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Informed consent was gained before the commencement of data collection. All procedures carried out in this study were approved by the Auckland University of Technology Ethics Committee (19/24)**.**

ETHICAL APPROVAL

Ethical approval for this research was granted by the Auckland University of Technology Ethics Committee (AUTEC; #19/24) originally on the 28th March 2019, with minor amendments approved on 15th April 2019 (see Appendix 1).

LIST OF COMMON ABBREVIATIONS

1RM	One repetition maximum.
CG	Closed grip
Dx2	Start position to beginning of second pull.
DxL	The furthest point forward to the catch position.
DxT	Start position to the catch.
DxV	Start of the second pull to the furthest forward position.
FP	First pull.
HG	Hook grip
kg	Kilogram.
LS	Lifting straps
m/s	Meters per second
N	Newtons
PF	Peak force.
PP	Peak power.
PS	Power snatch.
PV	Peak velocity.
SP	Second pull.
SSC	Stretch shortening cycle
TP	Third pull.
W	Watts.

CHAPTER 1: INTRODUCTION AND RATIONALE

Background

Weightlifting movements such as the snatch and the clean and jerk mirror many athletic movements as they are ballistic and biomechanically similar to jumping, sprinting, and change of direction tasks (Cormie, McGuigan, & Newton, 2010). The snatch and the clean and jerk are the two exercises used within competitive weightlifting (Hori, Newton, Nosaka, & Stone, 2005). The snatch is a total body explosive exercise that requires the barbell to be lifted from the floor to an overhead position, whilst descending into a full squat, in one continuous movement. Therefore, multiple main muscle groups are used during the lift, including the gluteus maximus, hamstrings, quadriceps, and the trapezius (Graham, 2001). Due to the highly demanding mobility requirements of the full snatch, the power snatch (PS) is an appropriate alternative for a number of athletes as it requires the lifter to catch the barbell in a semi-squat position (i.e., thighs above the parallel position). Thus, the PS mimics the temporal requirements of the full snatch without the need for increased range of motion in the hip and knee region (Pennington, Laubach, De Marco, & Linderman, 2010; Barr, Sheppard, & Newton, 2013; Delextrat, & Goss-Sampson, 2010). However, previous research has suggested that the PS and full snatch exercises could have different kinetic and kinematic outcomes due to the difference in the catch position (Winchester et al. 2009). As the PS involves catching the barbell at a higher position, this requires the use of lighter loads, which enables the lifter to produce greater speeds and higher power outputs (Waller, Townsend, & Gattone, 2007). For example, a maximal attempt PS is typically 80-85% of a technically proficient weightlifter's full snatch (Dewar et al. 2018). Previous research has demonstrated that kinetic and kinematic characteristics of weightlifting movements determine the successful or unsuccessful outcome of these lifts (Akkus, H. 2012; Gourgoulis, Aggeloussis, Garas, & Mavromatis, 2009; Ikeda, Jinji, Matsubayashi, Matsuo, Inagaki, Takemata, & Kikuta, 2012). These two characteristics are typically the focus of coaches and athletes who are hoping to improve the successful execution of their lifts. According to Lee et al. (1995), the efficiency of the full snatch improves when an athlete can generate the required ground reaction force (GRF) in a shorter time frame (i.e., 0.2s before the barbell leaves the ground) when compared to an athlete who takes a longer time to generate the required GRF which potentially results in extra effort predominantly during the start of the lift (Lee, Huwang, & Tsuang, 1995). In addition, a more efficient bar path has been shown to increase peak force (PF) and peak power (PP) during the snatch (Winchester, Porter, & McBride, 2009). In most cases of successful snatch attempts, the trajectory of the barbell does not pass a vertical reference line that aligns with the starting position of the barbell (Gourgoulis, Aggelousis, Mavromatis, & Garas, 2000). Thus, optimizing the technique of a lifter will improve the training adaptations they receive from weightlifting-style movements. Although research suggests that horizontal bar path displacement is not enough to determine the performance outcome of the snatch, it is suggested that reducing horizontal displacement would be an efficient way to preserve a greater amount of energy which would increase the potential to lift greater loads (Stone, O'Bryant, Williams, Johnson, & Pierce, 1998).

During training and competition, athletes will use one of two types of grip variations whilst completing weightlifting movements; the closed hand grip (CG), which is a traditional grip of the barbell, or the hook grip (HG). Competitive weightlifters routinely utilize the HG, which is a method of holding the barbell by gripping the thumb between the barbell and the remaining fingers. Anecdotally, the HG prevents the barbell from rotating in the lifter's hand, thus enabling a secure grip (Tsuruda, 1989). A recent publication demonstrated an improvement of kinetic, kinematic, and qualitative performance variables of the power clean exercise when utilizing the HG (Oranchuk et al. 2018). During this study, 11 participants completed a 1RM test with either the HG or the CG in a randomised order 5-7 days apart from each other. The primary findings showed that the use of the HG resulted in an increased 1RM power clean, improved peak velocity (PV) and improved relative peak power at all measured intensities when compared to the CG condition. Additionally, the HG resulted in an increased catch height and subjective findings demonstrated that the participants felt they had a more secure grip and were more proficient whilst racking the barbell during the catch-phase of the lift. In training, athletes may also utilize lifting straps (LS), which loop around the individual's wrist and secures their hand to the barbell. Athletes and coaches report that a minimal amount of muscular effort is required to maintain a secure hold of the bar when utilizing either the HG or LS method. By requiring less muscular tension, the arms remain passive, leading to a greater force transfer from the prime movers of the legs and back, which facilitates greater force and power outputs (Tsuruda, 1989). Furthermore, it is believed that having passive arms during certain phases of weightlifting movements enables that barbell to remain close to the lifter's body, which leads to an optimized bar path (Drechsler, 1998). Thus, the use of LS would potentially increase athletic performance by reducing total fatigue, which will allow for the generation and maintenance of higher PF, PV, and power outputs. Due to these proposed performance-enhancing effects, the use of LS in official weightlifting competitions is prohibited. To date, no investigation has examined what influence the HG, CG, or LS has on the kinetic, kinematic, and qualitative performance variables of the PS.

Purpose statement

The primary purpose of this thesis was to compare the kinetic, kinematic, and qualitative outcomes of the PS with the HG, CG, and LS. This study included participants who were experienced with the use of HG and LS and was completed for the following reasons:

- To date, no known studies have compared the use of HG, CG, or LS during submaximal to maximal PS attempts.
- Previous research indicates that the use of HG and LS can improve barbell velocity, force, and power outputs for various exercises, meaning that the findings of this study could be used to clarify and/or confirm the findings of those previous studies with a separate WL movement (PS).

This thesis attempted to provide a connection between the research regarding HG, CG, and LS and its impact towards a 1RM PS performance. As previous research has looked at the influence of these grip variations separately, the findings of this study will be able to connect all three grip variations in the context of 1RM PS attempts.

Research aims and hypothesis

The main objectives of this thesis were to determine:

1. Which grip variation provides a greater performance benefit during a 1RM PS attempt.
2. Which grip variation produces the greatest ground reaction forces during the PS.
3. Which grip variation produces the greatest barbell velocity during the PS.
4. Which grip variation allows athletes to have greater subjective ratings during each phase of the PS.
5. Practical recommendations for coaches who are looking to improve the aforementioned qualities of training for their athletes.

It was hypothesized that the HG and LS would increase maximal lifting performance, and enable greater levels of force, velocity, and power to be generated compared to a standard CG method. It was also hypothesized that the HG and LS would enable an optimized bar-path when compared to the CG condition. Finally, it was hypothesized that participants' subjective ratings would largely reflect the positive kinetic and kinematic outcomes.

Structure of the thesis

This thesis consists of five chapters that all come together in a final general summary.

Chapter two consists of a literature review that covers aspects of weightlifting movements in general, followed by the specific kinetic factors during each phase of the full snatch movement. The kinematic factors of the bar path during each phase of the snatch will then be addressed. Finally, this review also covers the various grip types that athletes employ during lifting.

Chapter three outlines the experimental study design used to investigate the influence of the HG, LS, and CG on the kinetics, kinematics, and qualitative qualities of the PS. In addition, the research methodology used to answer the primary research questions is described along with the statistical analyses.

Chapter four consists of the results of each of the variables that were included in the experimental study. The results are presented as the mean and standard deviations of the combined male and female data as well as the mean and standard deviations of each sex.

Chapter five consists of the discussion of the results, followed by practical recommendations which are synthesised from the literature review and research findings. Practical recommendations regarding which grip variation to use in training are provided with the intention to guide athletes towards greater performance improvements with the PS. This chapter concludes with the limitations of the research and recommendations towards future research on this topic.

CHAPTER 2: LITERATURE REVIEW

Abstract

The primary weightlifting movements such as the snatch, the clean and jerk, and their associated derivatives, are conventional for strength and conditioning coaches due to the biomechanical similarities to tasks such as sprinting and jumping (Cormie, McGuigan, & Newton, 2010). The purpose of this literature review is to cover aspects of weightlifting movements in general, followed by the specific kinetic factors during each phase of the full snatch movement. The snatch is a highly dynamic movement that requires a barbell to be lifted from the floor to an overhead position in one continuous movement as the lifter descends into a full squat position. The power snatch (PS) is an alternative exercise that involves the lifter landing in an above parallel squat position, and the maximal load used is typically around 80-85% of a maximal full snatch attempt (Dewar, 2018). Kinetic factors, such as velocity and vertical ground reaction force (GRF), are said to be essential parameters of snatch performance with a range of velocities and GRFs being produced over various loads. The influence of load also appears to be a factor that can alter the kinematics of the snatch with lower intensities making a lifter move differently compared to attempts at a higher intensity. For example, a load of 40% 1RM does not require maximal force output to complete while a load of 100% 1RM would require the lifter to move with the intention of producing maximal force and velocity in an efficient manner in order to get the barbell high enough to be able to catch it in an overhead position. The bar path during a power clean has been quantified by Winchester et al. (2009), and four key horizontal metrics have been identified; 1) Dx2 which is the starting position to the beginning of the second pull (SP), 2) DxV which is the beginning of the SP to the most forward position, 3) DxL which is the most forward position to the catch and, 4) DxT which is the starting position to the catch. These metrics become useful as bar path efficiency can be a significant factor in successful snatch performance. Whilst Winchester et al. (2009) defined these horizontal metrics for the power clean, these same metrics can be applied to the performance of the PS. During the performance of weightlifting exercises, lifters will use one of three grip variations; hook grip (HG), closed grip (CG), or lifting straps (LS). Each of these grip types has previously been shown in the literature to alter the performance of the exercise under investigation. However, no known studies have compared the use of HG, CG, or LS during submaximal to maximal full snatch or PS attempts.

Introduction

Weightlifting movements such as the snatch and the clean and jerk mirror many athletic movements as they are ballistic and biomechanically similar to jumping, sprinting, and change of direction tasks (Cormie, McGuigan, & Newton, 2010). The snatch and the clean and jerk are the two exercises used within the sport of weightlifting (Hori, Newton, Nosaka, & Stone, 2005), which can be broken into two broad phases, as Figure 1 describes. The barbell rises via the person producing force into the ground (Figure 1, phase 1), while the second phase involves the lifter moving underneath the barbell as it continues to rise (Figure 1, phase 2). More specifically, these broad phases can be broken down into three primary steps; the first pull (FP), which is where the bar rises off the ground to approximately the mid-thigh. The second pull (SP) begins from approximately mid-thigh and finishes at a fully extended position, which is also known as the triple extension. Finally, the third pull (TP), which is the transition from triple extension into the receiving position under the barbell, which is overhead for the snatch or on the shoulders for the clean (Storey & Smith 2012). Although these aforementioned primary steps do not result in the full completion of either the snatch or clean and jerk, the similarity between the two weightlifting exercises is that they both involve the FP, SP, and TP. The triple extension component (i.e., the final explosive portion of the lift) is what practitioners are generally focused on to aid with the transference of muscular power to sporting activities that involve rapid hip, knee & ankle extension such as the vertical jump in basketball (Suchomel, Comfort, & Stone, 2015). Weightlifting movements have also been shown to produce higher PF, power outputs, and barbell velocities in comparison to very high force activities such as a maximal back squat, bench press, and/or deadlift (McBride, Triplett-Mcbride, Davie, & Newton, 1999). For example, during the SP of a maximal clean, peak power (PP) outputs can reach up to 7000 W (Newton, & Kraemer, 1994), and a 100 kg male lifter can produce around 3,000 W during the triple extension of the snatch. In comparison, a low velocity maximal squat attempt may produce upwards of 1,100 W (Kawamori et al., 2005). Furthermore, maximal strength exercises such as the squat involve a deceleration component towards the end of the lift, which can alter the force-velocity profile of an athlete compared to the aforementioned weightlifting exercises, which involve a continuous acceleration of the barbell towards the end of the lift (Suchomel, Comfort, & Stone, 2015). To put this into perspective, Newton, Kraemer, Häkkinen, Humphries, & Murphy (1996) found that a ballistic exercise such as the bench press throw will continue accelerating for up to 96% of its full range. Conversely, during a traditional bench press movement, peak barbell velocity (PV) will be reached at ~60% of the exercise's total range before deceleration begins. Such differences in the force-velocity profile of how exercises are performed need to be taken into consideration when seeking maximal transference towards an athlete's sport. While there are two predominate weightlifting movements, strength and conditioning coaches will commonly utilize derivatives of the traditional weightlifting exercises such as the power snatch (PS), power clean, clean pull, snatch pull, hang high pull, jump shrug, and mid-thigh pull in order to gain the benefit of the weightlifting movements without the need to learn or be mobile enough to complete the full version of the exercise (Suchomel, Comfort, & Stone, 2015). Weightlifting derivatives are additionally common due to the ability to overload the triple extension phase of the SP as becoming technically proficient at the traditional weightlifting movements can be very demanding.

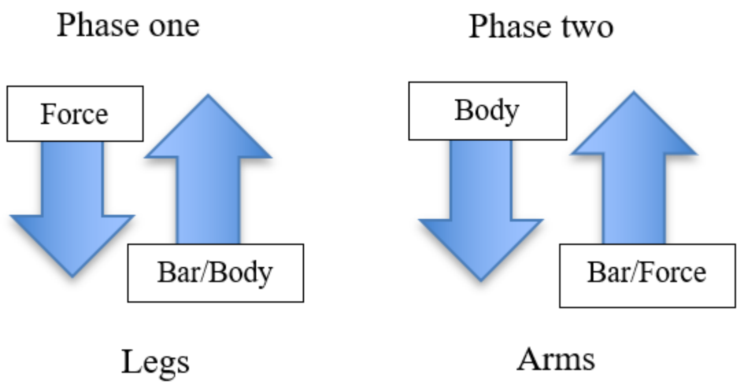

Figure 1. *The two distinct weightlifting phases adapted from Everett (2016).*

The purpose of this literature review is to cover aspects of weightlifting movements in general, followed by the specific kinetic factors during each phase of the full snatch movement. The snatch will be the predominant focus of this literature review as it relates to the PS research conducted for this thesis. Furthermore, due to the limited existing research on the PS, the majority of the research covered in this review pertains to the full snatch movement completed by competitive weightlifters either in training/research settings or in official competition. However, where possible, these findings will be related back to the PS to provide further context for this thesis.

The snatch

The snatch is a total body explosive exercise that uses multiple main muscle groups, including the gluteus maximus, hamstrings, quadriceps, and the trapezius (Graham, 2001). The snatch from the starting position to the catch can be completed in as little as 1.001 seconds in 56-62 kg elite junior male weightlifters (Campos, Poletaev, Cuesta, Pablos, & Deval, 2006). There are six distinct phases of the snatch that allow the bar to travel from the ground to an overhead position; The FP which initiates the barbell leaving the ground requires the lifter to extend their knees to a near fully extended position whilst keeping a consistent torso angle (Figure 2, a). A transition phase follows whereby the lifter will re-bend their knees by around 20° (Bartonietz, 1996) to get their knees under the barbell while shifting the torso to a near-vertical position (Figure 2, b). The SP requires the lifter to rapidly extend the hips, knees, ankles, & shoulders to maximally accelerate the barbell vertically and slightly away from their body (Figure 2, c). The turnover requires the barbell to rise vertically to ~62-78% of the lifter's height as the lifter begins to pull themselves underneath the barbell (Figure 2, d). The catch phase involves the lifter catching the barbell overhead with a straight locked arm position while flexing the knee and hip joints into a full squat position (Figure 2, e). Finally, rising from the squat position involves maintaining locked arms with the barbell overhead until the lifter is fully standing (Figure 2, f) (Storey, & Smith, 2012).

The power snatch

While Figure 2 demonstrates a full snatch, that requires the lifter to catch the barbell in a below parallel squat position, the PS requires the lifter to catch the barbell in an above parallel squat position. Due to the highly demanding mobility requirements of the full snatch, the PS is an appropriate alternative that mimics the full snatch without the need for increased ROM in the hip and knee region as a majority of sports do not require knee angles beyond 90° of flexion (Pennington, Laubach, De Marco, & Linderman, 2010; Barr, Sheppard, & Newton, 2013; Delextrat, & Goss-Sampson, 2010). Although research shows that increasing training frequency can improve mobility in resistance training (Krist, Dimeo, & Keil, 2013), most athletes will not have this luxury due to the demanding aspects of their sport on top of supplementary training (e.g., resistance exercise). The incorporation of the PS into an athlete's program can increase an athlete's relative power output (Waller et al. 2007). The improvement of the power to weight ratio of an athlete along with the addition of plyometric explosive-type exercises can be used as an indicator of sprint speed (Cronin, & Hansen, 2005). Therefore, strength and conditioning coaches who are attempting to increase the sprint speed of their athletes may benefit by adding the PS into the programme. Additional to sprint speed, evidence has shown that the power to weight ratio of intercollegiate athletes during the horizontal countermovement jump may be improved by incorporating the PS into a warm-up (Radcliffe, & Radcliffe, 1996). Whilst the snatch requires a lifter to catch the BB in an overhead position, if it is a goal of a strength and conditioning professional to overload triple extension then a snatch high pull may be all that is required.

Research has demonstrated that the kinetic and kinematic characteristics can determine the successful or unsuccessful outcome of the snatch (Akkus, 2012; Gourgoulis, Aggeloussis, Garas, & Mavromatis, 2009; Ikeda, Jinji, Matsubayashi, Matsuo, Inagaki, Takemata, & Kikuta, 2012). In particular, the amount of GRF, horizontal displacement, maximum height, vertical velocity of the barbell, and barbell path efficiency are the important kinetic and kinematic factors that can affect snatch performance (Harbili, & Alptekin, 2014). While the full snatch and the PS are somewhat similar, Winchester et al. (2009) do suggest that it is appropriate to assume they could have different kinetic and kinematic outcomes due to differences in the catch position. As the PS involves catching the barbell at a higher position, this requires the use of lighter loads, which aid in the athlete producing higher barbell velocities (Waller, Townsend, & Gattone, 2007). According to Dewar (2018), the maximal PS load is typically 80-85% of a technically efficient weightlifter's full snatch. Future research would need to identify the kinetic and kinematic differences between the full and the PS, as there is limited information available on this topic.

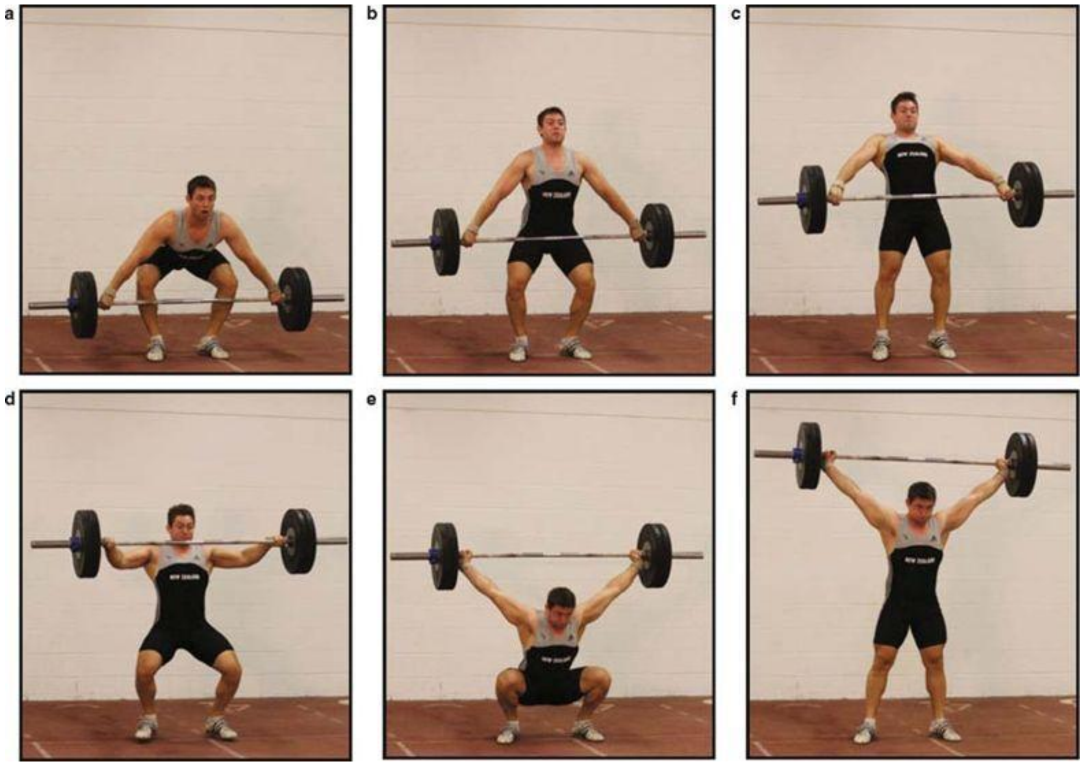

Figure 2. *The six phases of the snatch from the ground to above the head adapted from Storey, & Smith (2012).*

Kinetic factors

The GRF and barbell velocities are the two predominant kinetic factors that can influence the performance of the snatch. During the snatch, Baumann et al. (1988) state that as soon as the FP begins, the GRF accounts for all forces acting on the system and can impact the efficiency of the lift. However, the time-velocity relationship of the barbell (i.e., the speed of the barbell from the ground to the catch) is considered to be one of the most critical parameters of snatch performance (Isaka, Okada, & Funato, 1996; Baumann, Gross, Quade, Galbierz, & Schwirtz, 1988; Campos, Poletaev, Cuesta, Pablos, & Deval, 2006). According to Lee et al. (1995), the efficiency of the snatch improves when an athlete generates the required GRF in a shorter period of time during the FP and thus, the rate of GRF generation can greatly influence snatch performance (Yildiz, Ateş, Gelen, Çirak, Bakici, Sert, & Kayihan, 2018). Furthermore, Lee et al. (1995) stated that the athletes who take longer to generate the required GRF during the beginning of the FP are potentially using extra effort due to the longer duration of force production. The duration of the FP is significantly longer than the additional phases of the snatch and can be up to 0.47 seconds which can represent around ~40% of the total duration of the lift (Korkmaz, & Harbili, 2016; Campos, Poletaev, Cuesta, Pablos, & Deval, 2006). The FP of the snatch reaches an average acceleration of around 3.17-3.50 m/s^2 over the total duration of the phase from the ground to the beginning of the SP. At the end of the FP, the barbell reaches ~68.8-70.8% (e.g., 3.17-3.50 m/s) of its top speed in elite male weightlifters (Campos, Poletaev, Cuesta, Pablos, & Deval, 2006). The GRF during the snatch, as shown in Figure 3, will typically follow a curve where there is a small peak during the FP as the feet push into the ground, followed by a slight dip during the transition phase followed by a more significant peak during the SP (Baumann et al., 1988). In comparison, there have been two variations of velocity curves during the snatch, as depicted in Figure 4; one where there is a slight dip during the catch phase before the rise (Figure 4 left), the other where there is one continuous rise towards the catch phase without a dip (Figure 4 right). The latter is said to be the technique that elite lifters tend to use that involves minimal deceleration of the barbell until the catch phase. The resulting GRF differs during each phase of the pull as Lee et al. (1995) reported that the highest GRF during the FP occurs at the end of this phase as the lifter's knees begin to reach full extension. The end of the FP signifies the beginning of the transition phase as an athlete is attempting to initiate the powerful SP that follows.

The transition phase is one of the shorter durations of the snatch (i.e., ~0.15 seconds), accounting for ~9-11% of the total duration of the lift (Campos, Poletaev, Cuesta, Pablos, & Deval, 2006). As the knee bends during the transition phase, it is hypothesised that higher pretension of the quadriceps is developed to aid the explosive nature of the SP (Bartonietz, 1996). According to Campos et al. (2006), when a lifter utilises the double knee bend, this initiates the stretch-shortening cycle (SCC) of the hip and knee extensors to aid in the increase in vertical barbell velocity. This technique is said to be unique and universal to weightlifting and is a strategy that experienced lifters will tend to naturally use as the barbell passes the knee towards the transition phase. The double knee bend causes a slight bouncing action promoting the elastic energy that is stored within the muscle and tendons that can provide an extra layer of force supporting a higher velocity of the barbell (Campos, Poletaev, Cuesta, Pablos, & Deval, 2006). Although females may have less ability to use the stored elastic energy from the SCC compared to men (Hoover et al. 2006), this style of movement is common between both sexes. The acceleration of the barbell during the double knee bend and the SP of the snatch has also been correlated to performance ($r = 0.673$; $p = 0.033$) (Kipp, & Harris, 2014). A minimal decrease in vertical barbell velocity during the double knee bend is said to be a key variable of successful snatch attempts (Kipp, & Harris, 2014). In elite male weightlifters, a short decrease in barbell velocity of ~1.7% (~1.15-1.24 m/s) has been shown to occur during this transition phase (Campos, Poletaev, Cuesta, Pablos, & Deval, 2006; Bartonietz, 1996). A decrease in barbell velocity during the double knee bend would require the lifter to use a considerable amount of effort during the subsequent SP in order to restore the lost velocity during the transition phase.

Additionally, the bodyweight of the lifter will affect the velocity values as Campos et al. (2006) have stated that heavier lifters will attain higher vertical barbell velocities (p = <0.05) in comparison to the lighter weight categories. What is important to note about the results from Campos et al. (2006) is that they compared two groups (<62 kg vs. >85 kg). The lighter group had 17 lifters with an average height of 1.65 cm, a bodyweight of 58.92 kg, and lifted an average load of 108.38 kg. Conversely, the heavier weight group had 16 lifters with an average height of 1.78 cm, a bodyweight of 91.54 kg, and lifted an average load of 153.59 kg. It is likely that the higher barbell velocities exhibited by the heavier lifters is due to their greater portion of muscle mass, which results in a superior force-producing ability when compared to their lightweight counterparts.

The percentage of 1RM per repetition or the total load across a given set of each lift can also influence the amount of GRF produced. For example, increasing the weight from 30% to 70% of the 1RM with experienced male weightlifters has been shown to significantly increase the peak GRF during three repetitions of the snatch pull (Wicki, Culici, DeMarco, Moran, & Miller, 2014). Additionally, Jensen & Ebben (2002) support this by demonstrating as the load increases from 50-90% of an athlete's 1RM, there is a linear increase in peak GRF from 2818.4 ± 478.4 to 3479.4 ± 740.5N. In addition, as the load increases, the duration of the FP becomes greater, highlighting the fact that load makes a substantial contribution towards how fast an athlete moves the barbell. In comparison, the acceleration profile of the barbell during heavier weight snatch lifts is characterised to have smaller decreases in acceleration during the double knee bend but tends to slow down after this phase as force is being generated during the SP before the lifter fully extends their hips (Kipp, & Harris, 2014). The literature has reported that the FP is generally slower due to it being more strength orientated while the SP is much faster due to the high-power focus during this phase (Harbili, & Alptekin, 2014). Understanding the differences between the GRF during the FP and SP allows coaches and athletes to visualise the explosive nature that the SP provides.

Lifting experience is also another key consideration for coaches and athletes to bear in mind. When attempting loads of 90% of 1RM, Lee, Huwang, & Tsuang (1995) reported that the mean lifting time of the SP of the snatch was significantly higher, and the mean maximal barbell velocity was significantly lower for participants who are less skilled in the snatch. Further to this point, Hoover et al. (2006) demonstrated that national-level female lifters have lower maximal vertical velocities in comparison to international-level female lifters, which reiterates the velocity difference between experience levels. The differences between skilled and unskilled lifters can be due to technique factors combined with their limited experience to express the required forces in a short time frame. Brown and Abani (1985) explain that unskilled adolescent lifters display more variability in linear and angular acceleration parameters during a deadlift. Therefore, considering the extra skill required to perform an explosive movement such as a snatch, the difference between skilled and unskilled lifters has the potential to be far higher, creating considerably more variability in velocity ranges.

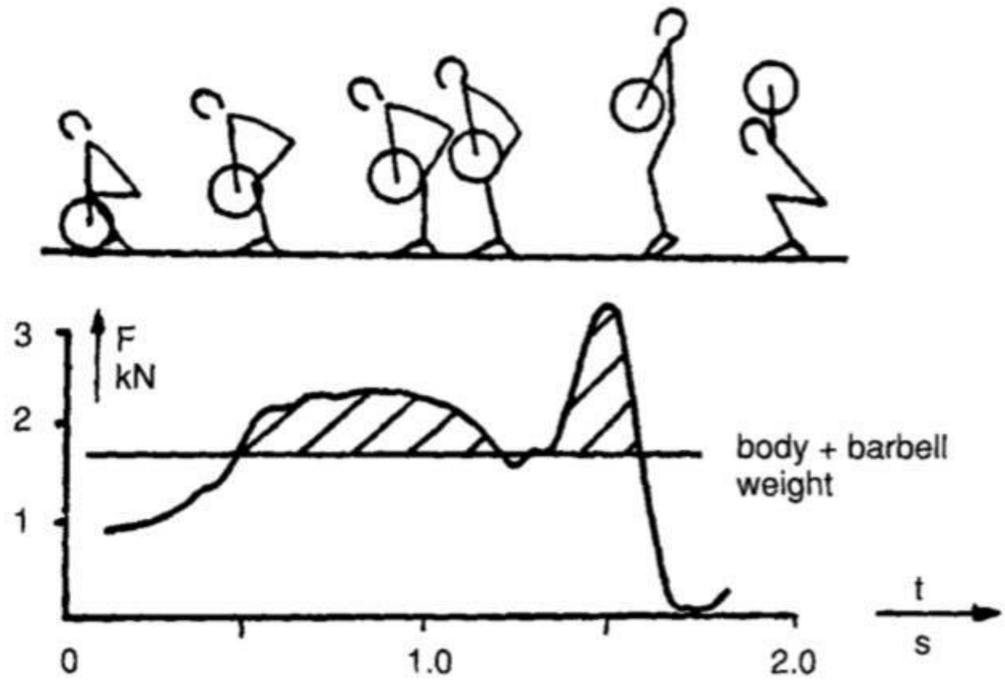

Figure 3. *The vertical ground reaction force of a full snatch adapted from Bartonietz (1996).*

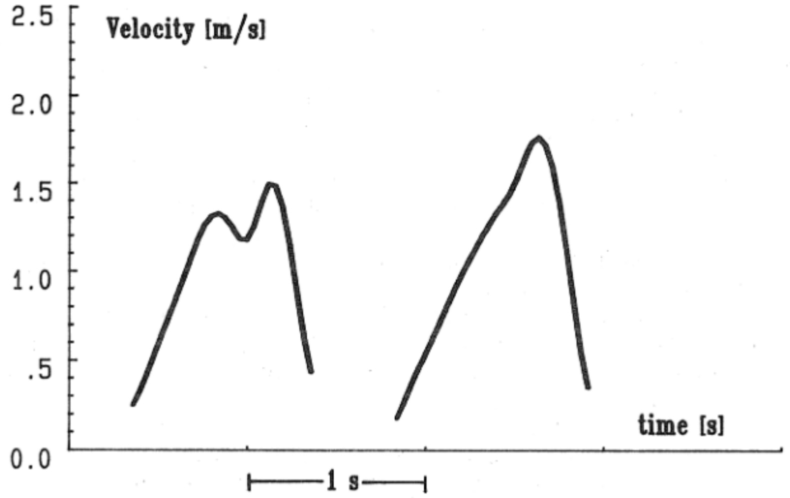

Figure 4. *The two variations of velocity curves during the snatch adapted from Baumann et al. (1988).*

Maximal barbell velocity is also positively correlated to the GRF produced during the SP of the snatch in elite-level male weightlifters (p = 0.02), showcasing the importance of developing both qualities (Krol, 2001). The barbell reaches its maximal vertical velocity of ~1.7-1.86 m/s in elite male weightlifters during the SP of a full snatch and this velocity range is sustained for ~0.15 seconds which accounts for ~12.3% of the total lift duration (Isaka, Okada, & Funato, 1996; Campos, Poletaev, Cuesta, Pablos, & Deval, 2006; Baumann et al. 1998; Gourgoulis et al. 2000). Comparatively, elite female weightlifters may produce a maximal vertical barbell velocity of ~1.65-1.68 m/s during the SP (Hoover et al. 2006; Akkus, 2012), which highlights the well documented sex-related difference in force-producing ability. A review completed by Storey & Smith (2012) reported that the absolute neuromuscular strength and power sex-related differences in recreationally trained males and females can range from 17% to 46%. Furthermore, when comparing the under 69 kg category (which at the time of publication was the only common body weight class between sexes) world record lifts over all age ranges (Table 1), there is a consistent sex-related difference in maximal performance of 15-20% (Storey & Smith, 2012). When adjusted for relative strength related differences in elite U.S.A weightlifters, females can reach up to 91% of the male values of the snatch (Stone, Stone, & Sands, 2007).

Table 1. *Sex and age-related differences in the 2011 under 69 kg world records adapted from Storey and Smith (2012)*

Category	**Lift**	**Male (kg)**	**Female (kg)**	**Percentage of the male record obtained by a female (%)**
Youth	Snatch	142	117	82.4
Junior	Snatch	158	123	77.8
Senior	Snatch	165	128	77.6

Finally, the catching phase requires a quick turnover to minimise the barbell's drop velocity, which can reach around 2.5 m/s after falling ~0.32m (Bartonietz, 1996). The first dip in Figure 4 outlines where the catching phase will typically occur, and it is ~0.23 seconds after the start of the lift, which accounts for 10.1-11.2% of the total lift duration (Campos, Poletaev, Cuesta, Pablos, & Deval, 2006). Collectively, such findings reiterate the need to strive for technical proficiency with the snatch to optimize the kinetically derived benefits from this movement.

Kinematic factors

According to Winchester et al. (2009), the critical bar path kinematics variables that are used to quantify changes in performance include an initial rearward movement of the bar during the FP (Figure 5, Dx2), a catch position behind the most forward bar position (Figure 5, DxL), and the amount of looping of the barbell (Figure 5, DxL) which should be less than the net rearward horizontal displacement (Figure 5, DxT). From a kinematic point view, the FP of the snatch involves the extension of the hip and knee with a consistent trunk angle throughout the movement, while the feet remain in complete contact with the ground (Bartonietz, 1996). While the hip extension is vital during the FP, too much can be detrimental due to the alteration of the barbell trajectory, which then becomes forward of the vertical line of reference (Bartonietz, 1996). Figure 5 shows the bar path of a PS where the lifter aims to maintain the trajectory of the barbell behind a vertical line from the barbell's starting position. In most cases of successful snatch attempts, the trajectory of the barbell does not pass a vertical reference line that aligns with the starting position of the barbell (Gourgoulis, Aggelousis, Mavromatis, & Garas, 2000; Ikeda, Jinji, Matsubayashi, Matsuo, Inagaki, Takemata, & Kikuta, 2012). A more efficient bar path has been shown to increase PF and PP during the snatch (Winchester, Porter, & McBride, 2009). Barbell efficiency can be referred to as the minimal distance that the barbell must travel from the starting position to the catch phase and this involves predominately vertical barbell displacement. The total amount of horizontal displacement from the barbell leaving the ground to the catch position (Figure 5, DxT) is an essential kinematic factor as previous studies have shown that up to 64% of unsuccessful PS attempts demonstrate a reduced rearward displacement of the barbell which results in the lifter attempting to catch the barbell in a forward position (Stone, O'Bryant, Williams, Johnson, & Pierce, 1998). From a training perspective, Winchester et al. (2009) have shown that following augmented feedback during PS training, increased rearward displacement of the barbell from the FP to the SP (Figure 5, Dx2) was shown to be a positive outcome for PS performance. The authors also concluded that the total amount of barbell displacement between the most forward position during the SP to the catch position (Figure 5, DxL) is also associated with higher successful attempts of the PS with a recommendation that the total horizontal displacement of the barbell should be <20 cm (Winchester, Porter, & McBride, 2009). Although research suggests that horizontal bar path displacement is not enough to determine the performance outcome of the snatch, it is recommended that reducing horizontal displacement would be an efficient way to preserve a more considerable amount of energy which would increase the potential to lift higher loads (Stone, O'Bryant, Williams, Johnson, & Pierce, 1998). Additionally, Gourgoulis et al. (2000) stated that small amounts of horizontal barbell displacement could be an estimate of a useful application of muscular power, providing it is not excessive, which can occur as the lifter fully extends the hip, knee and ankle joints during the SP. Furthermore, Szabo (2019) presented the idea that the centre of gravity is the product of the lifter + the barbell, which suggests that a minimal amount of horizontal displacement is adequate for keeping the centre of gravity in line. In addition to this, Campos, Poletaev, Cuesta, Pablos, & Deval, (2006) argue that the variation of the angular kinematics of the lifter is not significantly related to the vertical velocity of the barbell as the athlete and the barbell are two separate entities stating that each individual will move towards their own unique movement pattern.

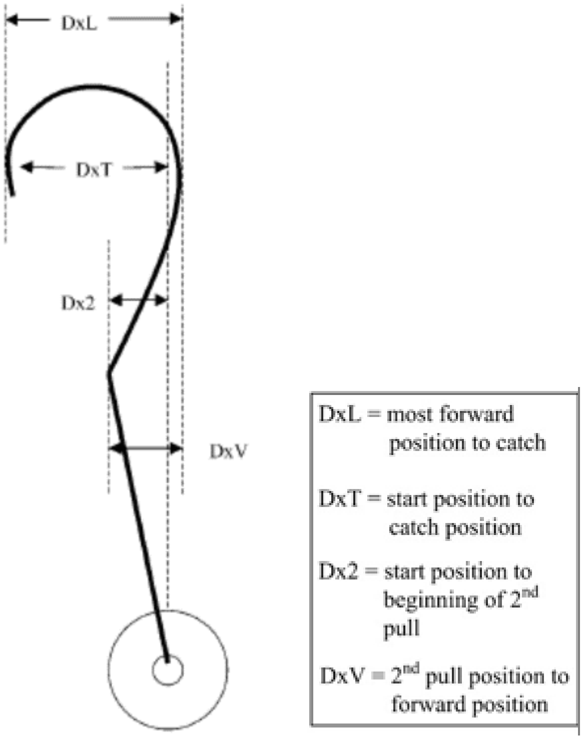

Figure 5. *Description of bar path kinematic variables used to assess quantitative changes in bar path before and after training (Winchester et al., 2009).*

Anthropometric factors can influence the way that the barbell travels throughout the lift. For example, an athlete with longer limbs will typically have a more considerable bend in the knees, reaching ~80° of flexion while a shorter athlete will not bend the knees as much with a knee angle of ~47° of flexion before pulling bar (Bartonietz, 1996). While it is evident in the literature that heavier weight classes can lift greater weights, it has also been shown that heavier categories are also more efficient as they manage to maintain longer barbell trajectories which allows them to hold the barbell for a longer period, allowing them to have greater control (Campos et al. 2006) which can also be due to the taller nature of these athletes. These taller lifters have been shown to produce a long vertical bar trajectory during the FP ($p = 0.011$) and greater bar height loss during the catch in comparison to lighter shorter lifters (Campos et al. 2006). The height of the barbell before an athlete completes the catch phase reaches around 69.2-70.3% of the lifter's height regardless if they are tall or short (Campos, Poletaev, Cuesta, Pablos, & Deval, 2006). This distance allows the athlete enough time and space to be able to move underneath the bar in order to be able to catch the bar overhead.

Types of grip

Grip strength has been shown to differentiate the performance of an elite level athlete compared to their sub-elite comparison. This is seen in the review by Cronin, Lawton, Harris, Kilding, &

McMaster, (2017) who found that successful elite-level athletes have greater hang grip strength than their less successful sub-elite counterparts in sports that involve holding onto an object such as baseball, climbing and, bowling. While grip strength is a factor within itself, the type of grip has been shown to influence the electromyographic [EMG] activity during the deadlift. Pratt et al. (2020) looked at the influence of the CG, HG, and mixed grip [MG] during 50, 70, and 90% of a deadlift 1RM (male; n=15, female; n=14). What they found was that regardless of grip orientation, PV was the same, although the MG allowed a lower EMG reading where they concluded that less effort was used during the MG in comparison to the HG and CG. During weightlifting training and competition, athletes will use one of two types of grip variation while completing weightlifting movements; the closed hand grip (CG), which is a traditional grip of the barbell, or the hook grip (HG).

Hook grip

Competitive weightlifters routinely utilize the HG, which is a method of holding the barbell by gripping the thumb between the barbell and the remaining fingers, as shown in Figure 6. Anecdotally, the HG prevents the barbell from rotating in the lifter's hand, thus enabling a secure grip (Tsuruda, 1989). A recent publication demonstrated an improvement of kinetic, kinematic, and qualitative performance variables of the power clean when utilizing the HG (Oranchuk et al. 2018). During this study, 11 participants completed a 1RM test with either the HG or the CG in a randomised order 5-7 days apart from each other. The primary findings showed that the use of the HG resulted in an increased 1RM power clean, improved PV, and improved relative PP at all measured intensities when compared to the CG condition. Additionally, the HG resulted in an increased catch height, and subjective findings demonstrated that the participants felt as if they had a more secure grip and were more proficient while racking the barbell during the catch-phase of the lift.

Figure 6. *The hook grip, adapted from Oranchuk et al. (2019).*

Closed grip

The CG involves the athlete grabbing the barbell with their thumb on the outside of their fingers, as demonstrated in Figure 7. Compared to the HG, the CG requires the lifter to actively squeeze the bar, which, when compared to the HG, requires a more considerable amount of tension produced in the forearms (Tsuruda, 1989). Contrary to the HG, the CG has shown to provide a lower 1RM, PV, PP, and a lower catch height at intensities above 84% in the power clean with trained male athletes (Oranchuk et al. 2018). The research revolving around the CG is limited within exercises that require the use of a barbell, and further research is necessary to showcase the limitations or benefits of using the CG for training purposes.

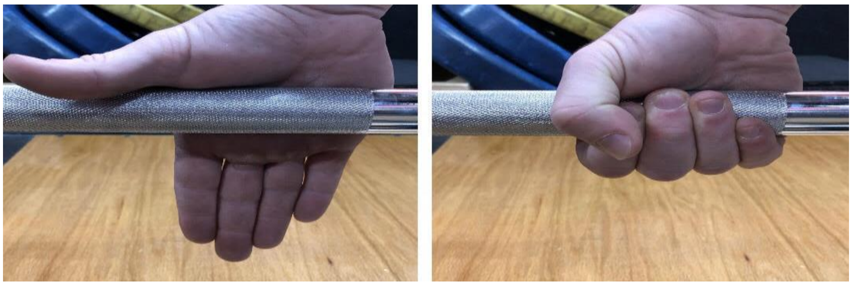

Figure 7. *The closed hand grip.*

Lifting straps

Athletes may also utilize LS, which loop around the lifter's wrist and secures their hand to the barbell, as shown in Figure 8. Athletes and coaches report that a minimal amount of muscular effort is required to maintain a secure hold of the barbell when utilizing either the HG or LS method. By requiring less muscular tension, the arms remain passive, leading to a higher force transfer from the prime movers of the legs and back, which facilitates greater force and power outputs (Tsuruda, 1989). Furthermore, it is believed that having passive arms during certain phases of weightlifting movements enables that barbell to remain close to the lifter's body, which leads to an optimized bar path (Drechsler, 1998). The use of LS requires the athlete to manually wrap the straps around the barbell while setting up their starting position. Indirectly, the use of LS during the deadlift has been shown to allow an athlete to produce higher forces at a slower speed which allows a higher amount of work to be performed (Coswig, Machado Freitas, Gentil, Fukuda, & Del Vecchio, 2015). The ability to complete a higher workload during the deadlift was due to decreased fatigue in the forearm muscles, which allowed a greater emphasis to be placed on the larger prime mover muscle groups (Coswig, Machado Freitas, Gentil, Fukuda, & Del Vecchio, 2015). Previous work by Hori et al. (2010) supported these findings and demonstrated that performing the clean pull exercise with

LS resulted in superior velocity, force, and power outputs. Thus, the use of LS would potentially increase athletic performance by reducing total fatigue, which will allow for the generation and maintenance of higher PF, velocity, and power outputs. Due to these performance-enhancing effects, the use of LS in official weightlifting competitions is prohibited according to the International Weightlifting Federations' technical and competition rules and regulations (2020). A recent study by Cowan & DeBeliso (2017) compared the effects of LS to a CG condition on the force output during the performance of a 1RM power clean. The results of this study found that completing a power clean using the CG method resulted in a significantly lower 1RM performance compared to performing a power clean using LS. Interestingly, peak GRF was substantially lower for the LS group at 70%. The authors suggested that the use of LS allowed the participants to exert less effort during the 70% 1RM condition when compared to the CG group, which resulted in the significantly lower GRFs. However, coaches will need to be aware that the use of LS can alter an athlete's routine towards their starting position. Stromback, Aasa, Gilenstam, and Berglund, (2018) found that the frequent use of LS while deadlifting increases the injury potential by up to 86% in powerlifters due to a different starting position set up.

Figure 8. *Lifting straps.*

Conclusion

The snatch is a total body exercise that has many potential performance improvement outcomes. Ground reaction force and barbell velocity are two kinetic factors that correlate during the FP and the SP of the snatch. The velocity relationship of the barbell in particular is considered to be one of the most critical parameters of the snatch performance. In addition, the ground reaction force plays a key part during the FP with athletes who take longer to generate these forces are using more effort than the counterparts who generate these forces quicker. In the literature, four kinematic variables are used to quantify bar path efficiency. An optimal bar path appears to move toward the lifter during the FP, away from the lifter during the SP, and slightly behind the lifter during the catch. An optimal bar path can, therefore, potentially aid the lifter in a successful catch without losing the barbell forwards or behind them. Additionally, the use of LS and the HG can potentially allow a lifter to complete a more substantial amount of total work (Coswig, Machado Freitas, Gentil, Fukuda, & Del Vecchio, 2015) and may also result in an increased 1RM as Oranchuk et al. (2018) found during their research with the power clean. As total volume/intensity is the most significant contributor towards strength/hypertrophy adaptation (Colquhoun et al. 2018), the use of LS or the HG may increase the overall effectiveness of training. However, coaches will need to be aware that the use of LS can possibly alter an athlete's routine towards their starting position. Whilst grip has been researched within the literature, it is evident that there is no guidelines towards whether the HG, CG or LS may or may not be beneficial towards PS performance.

CHAPTER 3: RESEARCH DESIGN

Study design

This study used a quasi-experimental method using a within-subject repeated measures design. Ten participants undertook a four-week intervention that involved one familiarisation session followed by three maximal testing sessions (1RM) of the PS using either a HG, LS or CG. Each testing session was completed five to ten days apart in a randomized order to encourage the full recovery of each participant. Participants resumed their regular training between testing sessions but were required to refrain from vigorous exercise at least 24 hours prior to testing.

Participants

Eleven resistance-trained individuals initially volunteered to participate in this study (male; n=6, female; n=5). Due to one participant failing to reach the criteria of being capable to PS 75% of their body weight, they had to be excluded from the study. This left the total amount to be 10 participants (male; n=5, female; n=5). All remaining participants reached the following eligibility criteria of; 1) capable of PS at least 75% of their body weight, 2) at least 6-months experience with the use of HG, and LS, 3) aged between 18-45, 4) free from acute or chronic injury, and 5) not currently using anabolic steroids. The participants were competitive weightlifters (n=5), CrossFitters (n=3), and recreational lifters (n=2). Participant anthropometric characteristics are outlined in Table 1. Informed consent was gained before the commencement of data collection. All procedures carried out in this study were approved by the Auckland University of Technology Ethics Committee (19/24)**.**

Table 2. *Anthropometric characteristics of all participants.*

	Age (years)	**Height (cm)**	**Weight (kg)**
Males	26.8 ± 3.7	178.9 ± 6.6	88.4 ± 9.8
Females	28.6 ± 5	165.9 ± 5.5	71.8 ± 8.8
Male/female	27.7 ± 4.2	172.4 ± 8.9	80.1 ± 12.39

Data collection and analysis

Power Snatch 1RM protocol

A standardized warm-up, as shown in Table 3, was performed by each participant prior to the specific warm-up. Each participant was then allowed between 1-2 sets of 3-5 reps on the 20 kg (males) or 15 kg (female) Olympic weightlifting bar (Eleiko Sport, Halmstad, SWE) prior to the specific warm-up. During each testing session, the participants performed the following sets and reps based off the CG 1RM that was acquired from the familiarisation session as part of their specific warm up; 8 reps at 50% of 1RM, 3 reps at 60% of 1RM, 1 rep at 70% of 1RM, 1 rep at 80% of 1RM, 1 rep at 90% of 1RM, and 1 rep at 95% of 1RM. After performing 95% of their estimated 1RM, each participant was consulted as to what weight they would like to attempt for their next attempts until a true 1RM was performed. The minimal increase in weight that they could increase was 1 kg and was self-selected due to what they thought they could complete. The criteria for a successful PS required the participant to catch the barbell with their thighs in an above parallel position before standing to an upright position (Storey & Smith, 2012). Additionally, each participant was required to finish the lift as per the International Weightlifting Federations technical and competition rules and regulations (2020) which only allowed a successful lift once the participant was standing erect with their arms and legs fully locked out with their feet in a parallel line to the plane of the trunk and the barbell. The participant could recover after they stood by taking a step forward or backwards as long as they stayed within the perimeter of the lifting platform which had a width of 3m and a length of 2m. As soon as the participant was motionless for a period of at least one second, they could then lower the barbell. Each participant was allowed up to three failed attempts before each procedure was finished. A minimum of five and a maximum of ten days separated each session. Every session after the familiarisation session was randomized to either the HG, CG, or LS using the website random.org. Commercially available LS were used by each participant and required the participant to loop a strap around the barbell which they held securely. The participants were not bound to the barbell via the LS and were free to release themselves from the barbell at any stage during the lift. Powdered chalk was provided by the researcher and was allowed during every session. No lifting belt, knee sleeves, wrist wraps of any form of supportive equipment was allowed during every session. No music was allowed, although verbal encouragement from the researchers was provided during every session.

Table 3. *Standardised dynamic warm-up protocol.*

Exercise	Duration/Repetitions
A: Cycle ergometer	5 minutes
B1. Side-to-side leg swings	10 repetitions
B2. Front-to-back leg swings	10 repetitions
B3. Body-weight squat	10 repetitions
B4. Forward lunge + vertical reach	10 repetitions
B5. Push up	10 repetitions
B6. Shoulder I, T, W, Y	10 repetitions

Kinetic analysis of the power snatch

A force plate (AMTI, Watertown, MA) was embedded into the lifting platform with a sample rate of 1000Hz. A linear position transducer (IDM Instruments) was embedded on the right side of the platform and positioned directly under the sleeves of the loaded barbell and attached with Velcro straps with a sample rate of 500 Hz. The LPT force plate system was interfaced with custom LabVIEW (National Instruments, Austin, TX) software. Data were filtered using a low-pass fourth-order zero-lag Butterworth filter with a cut-off frequency of 16 Hz based on residual analysis and visual inspection of the kinetic data, in-line with similar research by Comfort, Udall & Jones, (2012) and Kilduff et al. (2007). Peak values of the LPT were obtained from the first peak as the participant caught the barbell prior to standing up. Previous research has determined that maximal weightlifting kinetics are highly reliable within ($r \geq 0.969$, $p < 0.001$) and between ($r \geq 0.988$, $p < 0.001$) sessions (Comfort, 2013).

Kinematic analysis of the power snatch

An iPhone X was used to collect kinematic data at 1080p HD at 60 frames per second. The camera was positioned 5m away from the end of the platform of the participant's right-hand side. A reflective marker was placed at the end of the barbell to allow a digitized bar path to be created from Kinovea 0.8.15 software (see Appendix 7 for Kinovea analysis steps). The set-up of the camera and the specifications were in accordance with Garhammer & Newton (2013) for applied video analysis in weightlifting. The camera was fixed to a tripod that was 75 cm above the lifting platform and manually zoomed-in 2.5x so that the view included the surface of the platform and the peak height of the lift. A 90 cm scaling rod was applied to the platform with the same depth of field at the end of the barbell to give a known scaling measure for analysis in Kinovea. A piece of white tape was laid out over the center of the platform to ensure each lift was performed in the same standardised starting position. A recent study by Puig-Diví et al. (2019) have shown the Kinovea software to be a valid and reliable tool that is able to measure distances up to 5m from the object accurately and at an angle range of 90° ($r = 1$, $p = <0.05$) within the observations of multiple researchers.

Questionnaire

Following each set of the PS, a questionnaire derived from Oranchuk et al. (2018) (see Appendix 6) was administered to each participant and was measured by a five-point Likert scale. The questionnaire consisted of the following statements; 1) 'My grip felt secure off the floor,' 2) 'My grip felt secure in the second pull,' 3) 'I felt powerful' and 4) 'I felt fast catching the bar overhead.' Responses of 'one', 'two', 'three', 'four'' and 'five' correspond to 'completely disagree', 'disagree', 'neither agree nor disagree', 'agree' and 'completely agree', respectively. An additional visual analog scale (VAS) was used to quantify thumb/grip pain/discomfort. The VAS had two descriptors on either side; no pain and unbearable pain as the bar leaves the floor and was measured in centimeters.

Statistical analysis

Descriptive statistics were used to calculate the means and standard deviations for all measures throughout the study. A one-way repeated measures ANOVA was conducted to compare results between conditions. If significant differences ($p = <0.05$) were found, then a post hoc test using the Bonferroni correction was used to determine where exactly the differences were found between the three conditions. Finally, an independent samples t-test was carried out to compare the sex-related differences in performance variables for each condition. A sample size was not calculated, as *n* was limited by our ability to recruit sufficient participants within the timeframe of the master's thesis. Thus, it is possible that both null and significant findings could be attributed to insufficient power.

Effect sizes were assessed using the partial eta squared (η_p^2) method and for two group comparisons, the Cohens *d* formula was used. The interpretation of partial eta squared was assessed with the following criteria: trivial <0.02, small 0.02-0.13, moderate 0.13-0.26, large >0.26. Conversely, the effect size for Cohens *d* was assessed with these criteria: trivial <0.2, small 0.2-0.49, moderate 0.5-0.79, large >0.8.

CHAPTER 4: RESULTS

1RM

There were no significant differences of 1RM between the combined male and female grip conditions (p = 0.13, η_p^2 = .40). When adjusted for sex, females showed a significant 5.5% increase in 1RM using LS when compared to CG (p = 0.03, η_p^2 = .90). However, males had no significant difference between any grip condition (p = 0.42, η_p^2 = .44). Within each grip condition, the 1RM for the males were significantly greater for CG (34%, p = 0.01, d = 2.7), HG (33%, p = 0.01, d = 3.0) and LS (33%, p = 0.00, d = 3.3) when compared to females. The means and standard deviations of the combined male and females 1RM results are presented in Table 4. Table 5 presents the mean and standard deviations of each sex.

Table 4. *Average 1RM results for all participants between grip conditions.*

	Closed grip	**Hook grip**	**Lifting straps**
1RM (kg)	67.90 ± 17.34	71.2 ± 17.46	71.1 ± 16.72
N	10	10	10

*Indicates statistical significance (p<0.05)

‡Indicates statistical significance (p<0.01)

Table 5. *Average 1RM results for male and female participants between grip conditions.*

	Closed grip	**Hook grip**	**Lifting straps**
Male (kg)	81.60 ± 13.90‡	85.40 ± 13.05‡	85.00 ± 11.60‡
Female (kg)	54.20 ± 3.77	57.00 ± 3.67	57.2 ± 3.35*
N	5	5	5

*Indicates statistical significance between conditions relative to CG (p<0.05)

‡Indicates statistical significance within conditions (p<0.01)

Peak force

There were no significant differences in PF between grip conditions when the male and female data was combined (p = 0.36, η_p^2 = .26) or adjusted for sex (males p = 0.3, η_p^2 = .55, females p = 0.6, η_p^2 = .31). Within each grip condition, PF values for the males were significantly greater than females for CG (28%, p = 0.03, d = 1.7), HG (22%, p = 0.01, d = 2.3) and LS (24%, p = 0.02, d = 1.9). The mean and standard deviation of PF for both sexes are presented in Table 6. Table 7 presents the mean and standard deviations of each sex.

Table 6. *Average peak force results for all participants between grip conditions***.**

	Closed grip	**Hook grip**	**Lifting straps**
Peak force (N)	1790.93 ± 435.93	1776.90 ± 296.28	1879.10 ± 379.29
N	10	10	10

*Indicates statistical significance (p<0.05)

‡Indicates statistical significance (p<0.01)

Table 7. *Average peak force results for male and female participants between grip conditions*.

	Closed grip	**Hook grip**	**Lifting straps**
Male (N)	2077.27 ± 399.63*	1996.88 ± 215.85‡	2137.62 ± 295.69*
Female (N)	1504.60 ± 250.86	1556.92 ± 173.03	1620.59 ± 263.03
N	5	5	5

Indicates statistical significance within each condition (p<0.05)

‡Indicates statistical significance within each condition (p<0.01)

Peak velocity

There were no significant differences in PV between grip conditions when the male and female data was combined (p = 0.58, η_p^2 = .15) or adjusted for sex (male p = 0.79, η_p^2 = .14, female p = 0.66, η_p^2 = .34). In addition, there were no significant difference in PV within each grip condition between males and females; CG (4%, p = 0.30, d = 0.7), HG (2%, p = *0.70*, d = 0.3) and LS (1%, p = 0.9, d = 0.1). The mean and standard deviation of both sexes for PV is presented in Table 8. Table 9 presents the mean and standard deviations of each sex. Due to a technical malfunction during data collection for one participant, their PV data had to be excluded. Therefore, a collection of 9 participants PV was included in the final analysis.

Table 8. *Average peak velocity results for all participants between grip conditions***.**

	Closed grip	**Hook grip**	**Lifting straps**
Peak velocity ($m.s^{-1}$)	2.21 ± 0.15	2.23 ± 0.18	2.21 ± 0.22
N	9	9	9

*Indicates statistical significance (p<0.05)

‡Indicates statistical significance (p<0.01)

Table 9. *Average peak velocity results for male and female participants between grip conditions*.

	Closed grip	**Hook grip**	**Lifting straps**
Male ($m.s^{-1}$)	2.17 ± 0.17	2.21 ± 0.23	2.20 ± 0.28
Female ($m.s^{-1}$)	2.27 ± 0.11	2.26 ± 0.12	2.22 ± 0.15
N	9	9	9

*Indicates statistical significance (p<0.05)

‡Indicates statistical significance (p<0.01)

Kinematics

Although visually there appeared to be a difference in bar path between grip conditions (Figure 9 & 10), there were no significant differences between conditions for the combined male and female data for DxV (p = 0.28, η_p^2 = .31), Dx2 (p = 0.19, η_p^2 = .36), DxT (p = 0.31, η_p^2 = .25), or DxL (p = 0.29, η_p^2 = .27). The means and standard deviation of the combined male and female data for Dx2, DxV, DxT, and DxL are presented in Table 10. In addition, when adjusted for sex, there were no significant differences between grip conditions for males or females for Dx2 (males p = 0.25, η_p^2 = .60, females p = 0.44, η_p^2 = 42), DxV (males p = 0.55, η_p^2 = .33, females p = 0.57, η_p^2 = .31), DxT (males p = 0.17, η_p^2 = .70, females p = 0.45, η_p^2 = .41), or DxL (males p = 0.33, η_p^2 = .52, females p = 0.79, η_p^2 = .15). Table 11 presents the mean and standard deviations of each sex.

Table 10. *Average kinematic results of the Kinovea software for male and female participants.*

	Closed grip	Hook grip	Lifting straps
Dx2 (cm)	-2.89 ± 2.69	-2.01 ± 2.01	-4.06 ± 3.90
DxV (cm)	12.37 ± 4.89	10.88 ± 2.79	10.93 ± 3.63
DxT (cm)	3.65 ± 9.39	-1.16 ± 5.27	0.23 ± 9.39
DxL (cm)	8.34 ± 4.45	9.67 ± 3.19	8.00 ± 3.88
N	10	10	10

*Indicates statistical significance (*p*<0.05)

‡Indicates statistical significance (*p*<0.01)

Table 11. *Average kinematic results of the Kinovea software of all participants combined*

		Closed grip	Hook grip	Lifting straps
Dx2 (cm)	Male	-1.91 ± 2.23	-1.05 ± 1.50	-2.29 ± 1.42
	Female	-3.87 ± 2.97	-2.97 ± 2.27	-5.83 ± 4.95
DxV (cm)	Male	12.38 ± 6.11	10.44 ± 2.83	10.80 ± 4.27
	Female	12.37 ± 4.06	11.31 ± 3.01	11.01 ± 3.37
DxT (cm)	Male	5.93 ± 10.66	-1.55 ± 5.89	3.20 ± 7.52
	Female	1.34 ± 8.49	-0.78 ± 5.25	-2.74 ± 10.92
DxL (cm)	Male	9.21 ± 5.40	10.83 ± 3.59	8.54 ± 4.76
	Female	7.47 ± 3.69	8.51 ± 2.60	7.46 ± 3.24
N		10	10	10

*Indicates statistical significance (*p*<0.05)

‡Indicates statistical significance (*p*<0.01)

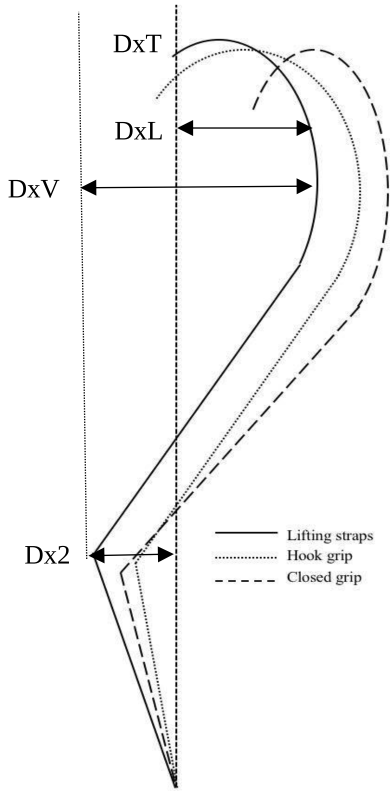

Figure 9. *Bar path comparison between lifting straps, hook grip, and closed grip for the combined male and female data.*

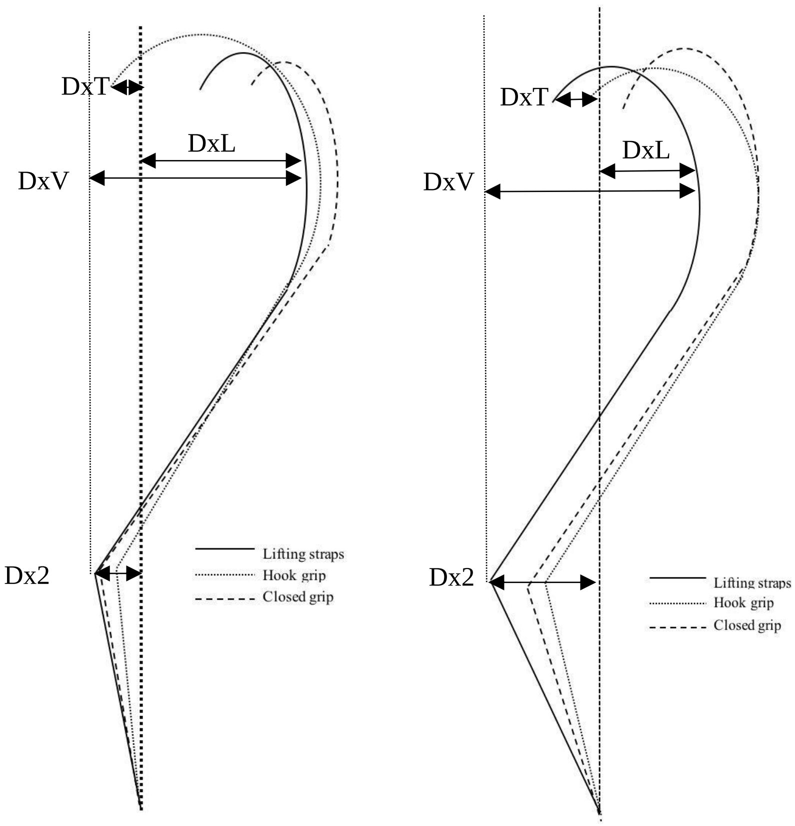

Figure 10. *Male (left) and female (right) bar path comparison between lifting straps, hook grip, and closed grip conditions.*

Questionnaire

Grip security off the floor and during the SP shows a statistically significant difference between conditions ($p<0.05$) for the combined male and female data. In particular, LS shows the greatest statistical significance of grip security off the floor and during the SP when compared to CG ($p<0.01$). Mean and standard deviations are presented in Table 12. Table 13 presents the mean and standard deviations of each sex. The following paragraphs will address each question.

1) *My grip felt secure off the floor*

There were significant differences between conditions for the combined male and female data (p = 0.02, η_p^2 = .60). Post hoc tests using the Bonferroni correction revealed that LS provided significantly greater grip security off the floor compared to CG (p = 0.01, d = 1.53) but not to the HG (p = 0.13, d = 0.62). HG and LS showed minimal differences (p = 0.67, d = 1.21). When adjusted for sex, there were no significant differences for males (p = 0.20, η_p^2 = .66) or females (p = 0.3, η_p^2 = .58) for each condition.

2) *My grip felt secure in the second pull.*

There were significant differences between conditions with the combined male and female data (p = 0.01, η_p^2 = .71). Post hoc tests revealed that LS provided greater grip security in the second pull than CG (p = 0.00, d = 1.89) and HG (p = 0.03, d = 1.10). When adjusted for sex, there were no significant differences for males (p =0.19, η_p^2 = .67) or females (p = 0.11, η_p^2 = .78) for each condition.

3) *I felt powerful*

There were significant differences between conditions for the combined male and female data (p = 0.02, η_p^2 = .64). Post hoc tests revealed that LS enabled all participants to feel more powerful compared to CG (p = 0.01, d = 1.56) but not to HG (p = 0.11, d = 0.37). When adjusted for sex, there were no significant differences between males (p = 0.09, η_p^2 = .80) or females (p = 0.27, η_p^2 = .58) for each condition.

4) *I felt fast catching the bar overhead.*

There were no significant differences between conditions for the combined male and female data (p = 0.06, η_p^2 = .51). When adjusted for sex, there were no significant differences in conditions between males (p = 0.14, η_p^2 = .73) or females (p = 0.39, η_p^2 = .47) for each condition.

Table 12. *Average descriptive statistics of the questionnaire for the combined male and female data.*

	Closed grip	Hook grip	Lifting straps
1) My grip felt secure off the floor	3.40 ± 1.70	4.10 ± .90	4.90 ± .30**
2) My grip felt secure in the second pull	3.20 ± 1.2	4.10 ± .90	4.90 ± .30**‡
3) I felt powerful	2.90 ± 1.00	3.30 ± 1.20	4.20 ± .60**
4) I felt fast catching the bar overhead	2.80 ± 1.30	3.20 ± .90	4.30 ± .70
N	10	10	10

*Indicates statistical significance relative to CG (p<0.05)

**Indicates statistical significance relative to CG (p<0.01)

‡Indicates statistical significance relative to HG (p<0.05)

Table 13. *Average male and female descriptive statistics of the questionnaire.*

	Sex	Closed grip	Hook grip	Lifting straps
1) My grip felt secure off the floor	Male	3.40 ± 1.30	4.00 ± 1.00	4.80 ± 0.50
	Female	3.40 ± 1.50	4.20 ± 0.80	5.00 ± 0.00
2) My grip felt secure in the second pull	Male	3.40 ± 1.30	4.00 ± 1.00	4.80 ± 0.50
	Female	3.00 ± 1.20	4.20 ± 0.80	5.00 ± 0.00
3) I felt powerful	Male	3.20 ± 1.10	3.60 ± 1.50	4.40 ± 0.60
	Female	2.60 ± 0.90	3.00 ± 0.70	4.00 ± 0.70
4) I felt fast catching the bar overhead	Male	3.20 ± 1.10	3.40 ± 0.90	4.40 ± 0.60
	Female	2.40 ± 1.50	3.00 ± 1.00	4.20 ± 0.80
N		10	10	10

*Indicates statistical significance (p<0.05)

‡Indicates statistical significance (p<0.01)

Thumb grip pain

In terms of thumb pain, there were no significant differences between conditions for the combined male and female data (p = 0.13, η_p^2 = .41). In addition, when adjusted for sex, there were no significant differences between males (p = 0.59, η_p^2 = .59) or females (p = 0.63, η_p^2 = .63) for each condition. The mean and standard deviations of combined male and female data are presented in Table 14. Table 15 presents the mean and standard deviations of each sex.

Table 14. *Average descriptive statistics of the visual analogue scale of the combined male and female data.*

	Closed grip	**Hook grip**	**Lifting straps**
VAS (cm)	1.52 ± 1.80	1.75 ± 2.12	0.58 ± 0.84
N	10	10	10

*Indicates statistical significance (p<0.05)

‡Indicates statistical significance (p<0.01)

Table 15. *Average descriptive statistics of the visual analogue scale of male and female data.*

	Closed grip	**Hook grip**	**Lifting straps**
Male (cm)	2.40 ± 2.18	2.92 ± 2.54	0.98 ± 1.07
Female (cm)	0.63 ± 0.77	0.57 ± 0.47	0.18 ± 0.17
N	5	5	5

*Indicates statistical significance (p<0.05)

‡Indicates statistical significance (p<0.01)

CHAPTER 5: DISCUSSION/CONCLUSION/IMPLICATIONS

Discussion

To date, only one investigation has examined the influence of the CG and the HG on a weightlifting movement, the power clean (Oranchuk et al. 2019). In addition, separate investigations have looked at the influence of LS in comparison towards CG during the performance of a clean pull (Hori et al. 2010), power clean (Cowan & DeBeliso, 2017) deadlift (Coswig et al. 2015) and lat pull down exercise (Valerio et al. (2019). Thus, to the best of our knowledge, this is the first study to compare the influence of the CG, HG, and LS on the kinetic, kinematic, and qualitative performance variables of the PS. It was hypothesized that the HG and LS would increase maximal lifting performance, and enable greater levels of force, velocity, and power to be generated compared to a standard CG method. It was also hypothesized that the HG and LS would enable an optimized bar-path when compared to the CG condition. Finally, it was hypothesized that participants' subjective ratings would largely reflect the positive kinetic and kinematic outcomes.

The main findings of this investigation were; 1) the use of LS in females resulted in significantly greater 1RMs when compared to CG ($p = 0.03$, $\eta_p^2 = .90$); 2) grip security was significantly improved off the floor for all participants with LS when compared to CG ($p = 0.01$, $d = 1.53$) ; 3) LS provided significantly greater grip security for all participants during the SP compared to CG ($p = 0.01$, $\eta_p^2 = .71$); 4) LS allowed all participants to feel significantly more powerful compared to CG ($p = 0.01$, $d = 1.56$) but not compared to HG ($p = 0.11$, $d = 0.37$). Secondary findings were; 1) there were no significant differences in PF ($p = 0.36$, $\eta_p^2 = .26$) or PV ($p = 0.58$, $\eta_p^2 = .15$) across any of the grip conditions; 2) no significant differences in bar path variables existed for any of the grip conditions ($p = >0.05$); 3) there were no significant differences in how fast each participant felt catching the bar overhead with any of the grip conditions ($p = 0.06$, $\eta_p^2 = .51$); 4) there were no significant differences in thumb grip pain between grip conditions ($p = 0.13$, $\eta_p^2 = .41$).

1RM

Surprisingly, there were no statistically significant differences in 1RM for each grip condition when male and female data was combined. These findings are in contrast to Oranchuk et al. (2018), which had shown that the HG resulted in significantly greater 1RM power clean performances when compared to a CG condition ($p = 0.001$). Whilst the study by Oranchuk et al. (2018) used males as their participants, it could be presumed that as the PS uses lower loads than the PC, grip strength may not be the issue when males and females are analysed as a whole. However, when adjusting for sex, LS provided a significant benefit to 1RM performance for females only (p = 0.03, η_p^2 = .90). The non-significant improvement in 1RM lifting performance with the use of LS in male participants contrasts the findings of previous investigations. For example, Hori et al. (2010) reported that LS produced a significantly higher 1RM clean pull compared to no LS (p = <0.05). In addition, Coswig et al. (2015) found that the use of LS allows a lifter to complete significantly more repetitions of the deadlift at 90% of their 1RM (p = 0.01, d = 1.3) compared to no LS. Finally, Cowan and DeBeliso (2017) found that the use of LS enabled lifters to perform a significantly higher 1RM power clean compared to no LS (p = <0.05).

Improved handgrip security off the floor is a key consideration for the improved 1RM performance during the LS condition for the female participants. Leyk et al. (2007) completed a handgrip strength assessment in 1654 males and 533 females with an additional 60 highly trained female athletes from sports that require handgrip strength. The investigation revealed that 90% of the females produced significantly less maximal force than 95% of the males (male: 540.8 ± 87.1, female: 329.4 ± 57.7 N, p = <0.01). Thus, it is likely that the difference in 1RM ability between grip conditions for the female participants may be partly attributable to a deficit in grip strength, which would have hindered their ability to perform the high-intensity lifts with maximal intent. While hand size was not measured for this study and could be considered a limitation, Leyk et al. (2007) found that hand dimensions (i.e. both hand length and width) have no significant influence on handgrip strength. Finally, it should be noted that the non-significant difference in 1RM's between groups can be due to insufficient power due to the low participant number within this study.

While the failed PS attempts were not included in the final data analysis, there were many instances where participants would attempt supramaximal loads with LS but would fail to complete the lift as they would catch the barbell in a forward position. These anecdotal findings suggest that the use of LS may be beneficial during supramaximal weightlifting derivative efforts that do not require an overhead catch phase. Within each grip condition, the 1RM for the males were ~33 – 34% greater when compared to females. These findings are in line with the previous work of Miller et al. (1993) which reported that females are ~52% as strong in the upper body and ~66% as strong in the lower body when compared to males. Further research should look to investigate the sex-related difference in strength and power measures during whole-body, ballistic movements such as the PS and other weightlifting derivatives.

Peak force

It was hypothesized that the HG and LS would increase maximal lifting performance and enable greater levels of force to be produced when compared to a standard CG method. However, there were no significant differences in PF between grip conditions when the male and female data was combined or adjusted for sex. As expected, within each grip condition, PF values for the males were significantly greater when compared to females (CG: 28%, p = 0.03, d = 1.7, HG: 22%, p = 0.01, d = 2.3, LS: 24%, p = 0.02, d = 1.9). The ~22-28% difference in PF producing ability between sexes is in line with previous evidence, which has shown a consistent sex-related difference of 15-20% in the maximal performances of under 69 kg male and female weightlifters (Storey & Smith, 2012). During the SP, LS provided a significantly greater sense of grip security when compared to a CG (p = 0.01, η_p^2 = .71). The subjective sense of improved grip security may have enabled the participants to exert more effort during the SP as PF values tended to trend upwards during this condition when compared to the HG and CG. However, further research with a larger participant pool is required to confirm the direction of this anecdotal finding.

Peak velocity

During the lift, PV occurred prior to the participant beginning to jump under the barbell, which is the highest point the barbell reaches before the participant recovers from the squat position. Surprisingly, there were no significant differences in PV between grip conditions when the male and female data was combined or adjusted for sex. These findings are in stark contrast to the work of Oranchuk et al. (2018), which demonstrated that the use of the HG during the power clean exercise significantly increased PV when compared to a CG condition.

The experience of each participant appeared to have them lifting with consistent velocities between conditions. For a lift to be successful, a number of kinetic and kinematic criteria must be met, and the results of the current investigation suggest that the optimal velocity threshold for our participants to perform a successful maximal PS attempt was between 2.17 – 2.27 m/s, regardless of the grip condition. Such findings agree with previous literature, which suggests that during a near-maximal to maximal full snatch attempt, the PV velocity of the barbell can range between 1.65 m/s to 2.28 m/s (Storey and Smith 2012).

As previously mentioned, there were many instances where participants would attempt supramaximal loads with LS. However, from visual observations, the primary reason for the participants failing to complete the lifts was due to a forward catch position as opposed to a noticeable decrease in barbell velocity. Thus, it can be suggested that to further develop PV during the SP of the PS, coaches, and athletes may look to use LS when performing submaximal to supramaximal snatch derivatives, which do not require an overhead catch phase.

Kinematics

Previous research by Winchester et al. (2009) had identified four variables associated with PS performance; 1) Dx2, 2) DxV, 3) DxT, and 4) DxL. Although there were no statistically significant differences in any of these four variables in both males and females, there was a visual difference in the bar path, as shown in Figure 9. The use of LS allowed the participant to keep the bar closer to the body while catching the barbell just above the initial starting position. All successful attempts across the grip conditions followed the recommendations of Winchester, Porter, & McBride (2009) by keeping the total horizontal displacement of the barbell <20 cm. Although the failed attempts did not get analysed, participants did repetitively say that they would fail due to catching the barbell too far forward. The CG did appear to have a lower 1RM due to a positive DxT as Stone, O'Bryant, Williams, Johnson, & Pierce (1998) previously stated that up to 64% of failed snatch attempts occur when the lifter catches the barbell in a forward position. Interestingly, the failed LS attempts were due to the lifter initially catching the barbell forward, but they did not have the confidence to recover from the catch position by stepping forward. Conversely, if the barbell did travel excessively forward during the CG condition, the participant would take recovery steps forward until they were able to stand in an upright stationary position. As previously specified, a successful lift required the participants to remain motionless with their knees and elbows fully locked out with the barbell overhead, but prior to this point, they were allowed to take recovery steps forward or backward as long as they stayed within the perimeter of the lifting platform. Of the kinematic variables, Dx2 was the greatest for LS, which could be linked to the greater grip security during the FP and SP, allowing the lifter to keep the barbell closer to their centre of gravity which helped prolong the FP until the knees were fully extended before initiating the SP.

Questionnaire

The results of the questionnaire indicated that LS and HG provided significantly greater grip security off the floor compared to CG. This supports the notion proposed by Tsuruda (1989) that the HG prevents the barbell from rotating in the lifter's hand, which provides a more secure grip. As LS and the HG voluntarily attach the lifter's hand to the barbell, it allows the lifter to have passive arms during the lift, which leads to an optimized bar path (Drechsler 1998). This key point can also explain why the participants were able to keep the bar closer to the vertical line of reference with the use of LS, as shown in Figure 9 and 10. The enhanced security of the grip that LS provided during the SP potentially allowed the participants to create non-significant GRF improvements due to greater confidence and a longer bar path from the starting position to Dx2, as shown in Figure 11. As maximal force takes time to generate, this could be the reason for the increase GRF of LS due to the longer bar path.

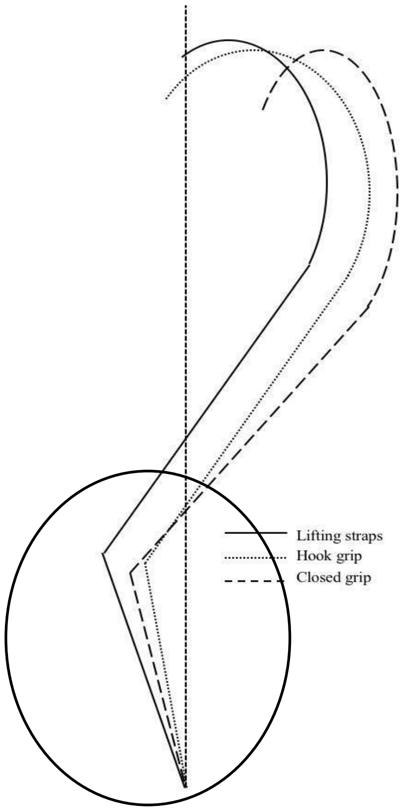

Figure 11. *The average length of the bar path of Dx2 between both sex of each grip condition.*

Grip pain

The results of the grip pain assessment were surprisingly non-significant between conditions. It was hypothesised that the HG, due to the pressure being applied to the thumb against the barbell would have caused a greater sense of thumb grip pain compared to LS. All participants were required to have at least 6-months experience with the use of HG, and the participants who were from a competitive weightlifting and/or a CrossFit background responded with less pain during the HG condition than the recreational lifters. Although training history was not recorded, the regular use of HG in their chosen sports likely contributed to their decreased pain sensation when compared to the experienced recreational lifter.

Practical applications

This study provided evidence to suggest that LS may be useful for female athletes who are wanting to increase their 1RM PS performance but may be limited by their grip strength capabilities. This study also indicated that both male and female lifters, who are looking to have greater grip security off the floor and during the SP, would benefit from the use of LS. Additionally, as LS allowed the participants to feel more powerful during these phases compared to the CG condition, they may provide a performance advantage when performing the PS. Although non-significant results were found for PV or GRF, athletes may benefit by using LS during supplementary weightlifting movements such as the snatch high pull exercise that does not require an overhead catch.

The results of the questionnaire indicated that LS and HG provided significantly greater grip security off the floor compared to CG, which is a key consideration for individuals wanting to pursue weightlifting exercises. However, while the VAS showed lower measures towards thumb grip pain during the PS with experienced lifters, it should be noted that non-experienced lifters would need some form of the transitional period into the HG.

Conclusion

This thesis fulfilled its aims of showing how grip can influence the kinetics, kinematics, and perceptual outcomes of a 1RM PS. Based on these findings, we concluded that the use of LS would provide a higher 1RM compared to a CG in female lifters who may have a grip strength deficiency. As PV was not influenced by grip condition, these findings suggest that as participants reach a maximal effort attempt, the barbell appears to move with a similar velocity regardless of the grip type. Whilst LS allowed the participants to attempt supramaximal loads; these attempts were deemed unsuccessful due to the participants catching the barbell in a forward position before dropping it. Such findings suggest that coaches and athletes may look to use LS when performing submaximal to supramaximal snatch derivatives, which do not require an overhead catch phase.

The CG, however, may be beneficial for an athlete who requires grip strength training due to a grip strength deficiency. Concerning grip security off the floor and during the SP, the use of LS provides a significantly greater sense of security when compared to the HG and CG in both males and females. Using LS will also allow athletes to feel more powerful, which could increase the confidence of athletes who are looking to overload the SP phase of the PS. Future research should expand on these findings with additional intensities (i.e., 70, 80, 90% of one's 1RM) along with biomechanical markers to assess limb angles with each condition

General summary

This thesis sought to determine the influence of the HG and LS on the kinetic, kinematic, and qualitative qualities of the PS. A thorough review of the literature involving the kinetics and kinematics of weightlifting movements, with a particular emphasis on the full snatch, was conducted. Additionally, this review briefly covered what grips are currently used when performing weightlifting derivatives. A range of kinetic and kinematic variables was used to address the primary research question. Additionally, a questionnaire was used to assess the qualitative nature of the PS under these three conditions. Ten resistance-trained individuals who were experienced with the HG and LS and were capable of PS 75% of their bodyweight participated in this study. Results indicated a significant increase in 1RM for females using LS compared to CG but not for males. Conversely, PV and PF had similar results regardless of grip condition. Qualitatively, LS provides greater grip security off the floor and during the SP while allowing the lifter to feel more powerful along with feeling faster while catching the barbell overhead.

Practical recommendations

There were several practical recommendations summarised throughout this thesis, as follows:

- Females, in particular, who may exhibit grip strength deficiencies, should consider using LS to aid in the development of their 1RM ability.
- Athletes such as sprinters and jumpers who require a powerful triple extension but who do not require grip strength would benefit by using LS due to the greater grip security during the SP and the qualitative nature of feeling powerful.
- Athletes who do not require grip strength or who have a grip strength deficiency would benefit by using LS due to the greater grip security during the SP and off the floor.
- Caution should be taken for athletes such as competitive weightlifters who are prohibited from using LS in competition to limit the use of LS, where possible to minimise any potential grip strength losses.

Limitations

The study completed in this thesis may have been limited by several methodological constraints, which are essential to note when interpreting the results from this study. The following are limitations that the researcher has suggested:

- Participant numbers were lower than expected partly due to several New Zealand weightlifting competitions coming up, which lowered the availability of potential participants.
- The variations between the sports of weightlifting, CrossFit, and the general recreational lifter may have influenced the results as each individual sport/lifter predominately uses a different grip condition during training (i.e., competitive weightlifters primarily use the HG compared to the recreational lifters).
- Grip strength was not measured during this study, which limited the ability to determine if grip strength influenced the results.
- The VAS only looked at thumb grip pain in general and not towards certain parts of the movement (i.e., FP, SP, or the catch).

Future research

This study has increased our understanding of the rationale behind why athletes and coaches would use the HG or LS during their training. However, the findings of this thesis, along with the limitations, have highlighted further areas of research. Future research in this area should look at the measurement of grip strength prior to the 1RM testing procedures, as research shows that there is clearly a difference in grip strength between sexes (Leyk et al., 2007). Furthermore, the inclusion of joint angle assessments would help to elucidate the influence that each grip type has on lifting performance. While the visual analogue scale in this study recorded thumb grip pain in general, adding an additional question such as "what phase of the lift did you feel the most thumb grip pain" would provide another level of perceptual information. Lastly, future researchers should investigate larger participant numbers to improve the statistical power of the results.

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APPENDICES

Appendix 1. *Ethical approval and conditional approval form.*

TE WĀNANGA ARONUI
O TĀMAKI MAKAU RAU

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

15 April 2019

Adam Storey
Faculty of Health and Environmental Sciences

Dear Adam

Re Ethics Application: **19/24 The influence of the hook grip and lifting straps on kinetic, kinematic, and qualitative performance variable of the power snatch**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 15 April 2022.

Standard Conditions of Approval

1. A progress report is due annually on the anniversary of the approval date, using form EA2, which is available online through http://www.aut.ac.nz/research/researchethics.
2. A final report is due at the expiration of the approval period, or, upon completion of project, using form EA3, which is available online through http://www.aut.ac.nz/research/researchethics.
3. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form: http://www.aut.ac.nz/research/researchethics.
4. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
5. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.

Please quote the application number and title on all future correspondence related to this project.

AUTEC grants ethical approval only. If you require management approval for access for your research from another institution or organisation, then you are responsible for obtaining it. You are reminded that it is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

For any enquiries, please contact ethics@aut.ac.nz

Yours sincerely,

Kate O'Connor
Executive Manager
Auckland University of Technology Ethics Committee

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
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www.aut.ac.nz/researchethics

28 March 2019

Adam Storey
Faculty of Health and Environmental Sciences
Dear Adam

Ethics Application: **19/24 The influence of the hook grip and lifting straps on kinetic, kinematic, and qualitative performance variable of the power snatch**

Thank you for submitting your application for ethical review. I am pleased to advise that the Auckland University of Technology Ethics Committee (AUTEC) approved your ethics application at their meeting on 25 March 2019, subject to the following conditions:

1. Confirmation that current students of the supervisor and clients of the primary researcher will not be recruited;
2. Provision of independent peer review;
3. Removal of the use of parent/guardian form;
4. Clarification of the inconsistences in section C.3.5.1 (participants respond to a flyer) and in the Information Sheet (have been approached in person) regarding the recruitment of participants;
5. Use of the current AUT logo on the advertisement
6. Amendment of the Information Sheet as follows:
    a. Provision of corresponding dates on both the Information Sheet and Consent Form;
    b. Update from 5-7 days to 7 days.

Please provide me with a response to the points raised in these conditions, indicating either how you have satisfied these points or proposing an alternative approach. AUTEC also requires copies of any altered documents, such as Information Sheets, surveys etc. You are not required to resubmit the application form again. Any changes to responses in the form required by the committee in their conditions may be included in a supporting memorandum.

Please note that the Committee is always willing to discuss with applicants the points that have been made. There may be information that has not been made available to the Committee, or aspects of the research may not have been fully understood.

Once your response is received and confirmed as satisfying the Committee's points, you will be notified of the full approval of your ethics application. Full approval is not effective until all the conditions have been met. Data collection may not commence until full approval has been confirmed. If these conditions are not met within six months, your application may be closed and a new application will be required if you wish to continue with this research.

To enable us to provide you with efficient service, we ask that you use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

I look forward to hearing from you,

Yours sincerely

Kate O’Connor
Executive Manager
Auckland University of Technology Ethics Committee

Cc: kennedy1992chris@gmail.com; dustinoranchuk@gmail.com; eric.helms@aut.ac.nz

Appendix 2. *Peer review.*

Auckland University of Technology Ethics Committee (AUTEC)

CONFIRMATION OF PEER REVIEW

[This exemplar may be used to confirm the results of an independent peer review of research. Other exemplars can be found on the Ministry of Health (HDEC) website at http://ethics.health.govt.nz/]

Applicant: Dr. Adam Storey

Title of project: The influence of the hook grip and lifting straps on kinetic, kinematic, and qualitative performance variables of the power snatch.

Peer review confirmation

The research proposal has been peer reviewed and it is confirmed that:

- the proposal has been peer reviewed by an experienced researcher in the field of study who is independent of the research and the researchers;
- the aims of the research are clearly identified;
- the research proposal is well designed and methodologically sound;
- the research proposal is supported by an appropriate literature review;
- the research procedures are appropriate to the aims of the research;
- the proposed study sample is appropriate;
- if the research is conducted according to the study design, it is expected to yield useful data within the proposed timeline;
- the researcher(s) has (or has access to) the necessary expertise to conduct the research and perform the procedures/techniques required by the research; and
- where relevant, all methodological issues have been resolved to the satisfaction of the peer reviewer.

Comments for AUTEC consideration

The summary of research and background are clear and concise and present a rationale for doing the study. The methods utilised are sound and have been utilised previously with other lifting methods enabling determination of differences in interventions with similar sample size to that in the proposed study. Criteria for choosing participants are suitable given the nature of the power snatch. The researchers listed have the necessary expertise to conduct the procedures and research.

Title	Dr	*First name*	André	*Last name*	Nelson
Signed				*Date*	7/04/2019

Course Chair: ABHD, ABHE, AMEP

Lecturer, Clinical Exercise and Sports Nutrition

College of Sport and Exercise Science

Research Associate, INSTITUTE OF SPORT, EXERCISE & ACTIVE LIVING (ISEAL)

VICTORIA UNIVERSITY
Room L311, Footscray Park Campus
Melbourne, Australia

Appendix 3. *Participant information sheet.*

Participant Information Sheet

Date Information Sheet Produced:

Project Title

The influence of the hook grip and lifting straps on kinetic, kinematic, and qualitative performance variables of the power snatch.

An Invitation

You are invited to be a part of a research project that is looking at the use of the hook grip and lifting straps and how these grip methods effect the kinetic, kinematic and qualitative variables associated with the power snatch exercise. It is important to note that if you do choose to take part in this research that your involvement is completely voluntary, and you can choose to withdraw at any point.

What is the purpose of this research?

The hook grip (HG) is a commonly used grip in Olympic weightlifting movements such as the power snatch. The HG requires the lifter to hold the barbell by gripping the thumb between the barbell and the remaining fingers. Anecdotally, the HG prevents the barbell from rotating in the lifter's hand, thus ensuring a secure grip. Additional grips that are used during the power snatch include the double overhand closed grip CG) and the use of lifting straps (LS). The purpose of this research is to compare the kinetic, kinematic and qualitative outcomes of the power snatch with and without the HG and LS. This research will go towards the completion of a dissertation as part of the Master of Sport and Exercise programme with AUT.

How was I identified and why am I being invited to participate in this research?

You were invited to be part of this research as you have responded to an advertisement of this study and expressed your interest to be involved.

In order to be a part of this study you will need to meet the following criteria:

- Be a resistance trained individual with at least 2 years training experience and ≥3-months of hook grip, closed grip and lifting straps experience.
- Between the ages of 18-35
- Injury free.
- Have the ability to power snatch 0.75x your own body weight.
- Currently not using anabolic steroids.

If you do not understand the above criteria, please contact the primary researcher for more information. Additionally, if you do not meet the above criteria then unfortunately you will not be able to participate in this study.

What will happen in this research?

This study involves four testing sessions separated by 7 days each. Each session will require you to undertake a 1RM power snatch test. The first session will involve a familiarisation session that will be approximately 90 minutes. The 3 follow up sessions will be 1-hour each which will involve you completing a 1RM power snatch with the use of lifting straps, hook grip or closed hand grip on top of a force plate. You will also be video recorded using 2D kinematic software at AUT Millennium. Following this you will be asked to answer a short questionnaire consisting of four questions. The power snatch testing sessions will be carried out a total of four times; Familiarisation session, hook grip, double overhand and straps with a total time requirement of 5 hours over 4-weeks.

What are the discomforts and risks?

You will be required to perform sub-maximal and maximal power snatch attempts during each session and as a result you will experience a short duration of discomfort for these maximal tests. However, these tests will be similar to the intensity to that of your regular training.

How will these discomforts and risks be alleviated?

Experienced coaches will be monitoring you during the maximal exercise tests and will ensure that you are not putting yourself in danger. In addition, you may choose to withdraw from the study at any stage prior to the completion of the data collection without the need to provide a reason.

What are the benefits?

A key benefit of taking part in this study will be that you will have access to your data obtained via this study which includes the kinetics and kinematics of your personal lifts. You will be contributing to research in the strength and conditioning field that could help to improve the implementation of Olympic lifts for athletes involved in higher level sport. This research will go towards the completion of a thesis as part of the Master of Sport and Exercise programme with AUT.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

All data that is collected will only be available to the research team. No information identifying you as the participant in this research will be included in any of the research reports or publications.

What are the costs of participating in this research?

The only cost for your participation in this research is your time. If you choose to participate you will take part in four power snatch 1RM testing sessions over a four-week period that will be approximately 1 hour in duration each. All testing will take place at AUT Millennium, 17 Antares Place, Mairangi bay, Auckland.

What opportunity do I have to consider this invitation?

If you would like to take part in this research, it is asked that you do so within two weeks of receiving this information.

How do I agree to participate in this research?

In order to take part in this research you will need to first contact the primary researcher (details at the bottom of this form). You will need to complete a consent form which will be provided to you once you have expressed your interest. Once the consent form has been completed the primary researcher will be in contact with you to commence the process.

Will I receive feedback on the results of this research?

You will have the option of receiving a summary of the findings from the research. Once these are available you can have them sent to your postal address as a hard copy or receive an electronic copy via email. Any data that will be used for publications, presentations, and further investigations in the future will be encoded in such a way that it will not be possible to identify subjects' data in any publication from this work (i.e. all data de-identified and aggregated).

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr. Adam Storey, adam.storey@aut.ac.nz, (021 2124200)

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Chris Kennedy, chris.kennedy@aut.ac.nz*, 0210348289*

Project Supervisor Contact Details:

Dr. Adam Storey, adam.storey@aut.ac.nz, (021 2124200)

Approved by the Auckland University of Technology Ethics Committee on 15/4/2019, AUTEC Reference number *19/24*.

Appendix 4. *Recruitment flyer.*

REQUEST FOR STUDY PARTICIPANTS

Project title:

<u>The influence of the hook grip and lifting straps on kinetic, kinematic, and qualitative performance variables of the power snatch</u>

Are you:

1. A current strength and power enthusiast (i.e. weightlifters, sprinters, jumpers, and/or throwers) with the ability to power snatch ≥ 0.75x body mass
2. Experienced with the use of hook grip and lifting straps during the power snatch?
3. Male or female aged between 18-35 years
4. Free from acute or chronic injury
5. Not currently using any performance enhancing or banned substances (World Anti-Doping Agency 2019)

Purpose of the study:

The hook grip has been shown to improve power clean performance variables including an increased 1RM, peak velocity and peak power at various intensities. Lifting straps have also been shown in research to increase ones 1RM during maximal lifting In power clean performance with no studies to date been completed during the power snatch. It is hypothesised that the use of hook grip or lifting straps during the performance of the power snatch may also result in an improvement in these areas. Therefore, the purpose of this investigation is to assess and compare the effects of using lifting straps, the hook grip or the closed hand grip method on the performance of the power snatch over a 4-week period.

What is involved:

Familiarisation Testing (Session 1):

Prior to the start of the study, you will be asked to complete an informed consent form. If you decide to proceed with the study, you will then complete a familiarisation session which includes a maximal (1RM) power snatch test using a closed grip. Total approximate time = 90 minutes maximum,

Testing (Session 2, 3 and 4)

During session 2, 3 and 4, you will then be asked to perform a 1RM power snatch test using either lifting straps, a hook grip or a closed grip. The order of these conditions will be randomised. Seven days will separate each session to ensure full recovery between each 1RM test. Between training sessions, you may recommence your normal training but you will be asked to refrain from all exercise 12 hours before each intervention session. Total approximate time: 1 hour each.

Benefits of the study:

You will benefit from having expert Olympic lifting coaching while receiving information regarding your force and power producing ability which will be applicable to your sporting endeavours. We will also be able to determine the type of grip that will allow a maximal performance benefit for your power snatch. Additionally, you will be contributing to the current body of knowledge in strength and power field.

Whom do I contact for further information about this research?

Researcher **Chris Kennedy** PH: 021 0348289 E: kennedy1992chris@gmail.co.nz
Project supervisor **Dr. Adam Storey PH:** 021 2124200 E: adam.storey@aut.ac.nz

Appendix 5. *Participant consent form.*

Consent Form

For use when laboratory or field testing is involved.

Project title:

The influence of the hook grip and lifting straps on Improvement of kinetic, kinematic, and qualitative performance variables of the power snatch with the hook grip.

Project Supervisor: *Dr Adam Storey*

Researcher: *Chris Kennedy*

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 07/04/2019
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ I am not suffering from current injury or illness that impairs my physical or mental performance to perform the tasks required nor am I outside the limits of the required age range of 18 to 35 years.
- ○ I understand that I am required to be experienced in resistance training with at least 6 months of hook grip, closed grip and lifting strap experience and are capable of power snatching 1x body weight.
- ○ I am not currently using anabolic steroids.
- ○ If I withdraw, I understand that all relevant information including tapes and transcripts, or parts thereof, will be destroyed.
- ○ I understand that a 2D motion capture system will be used and that the copyright of the images obtained belong to the primary researcher.
- ○ I agree to take part in this research.
- ○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Participant's signature: ……………………………………………………………………………………………………

Participant's name: ……………………………………………………………………………………………………

Participant's Contact Details (if appropriate):

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

Date:

Approved by the Auckland University of Technology Ethics Committee on 29/03/2019 AUTEC Reference number 19/24

Note: The Participant should retain a copy of this form

Appendix 6. *Questionnaire and visual analogue scale.*

Questionnaire

For each of the questions below, circle the response that best characterises how you feel about each statement following your 1RM power snatch, where: 1 = Completely disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Completely agree

For the visual analogue scale, please mark a reference point on the line in regard to the pain/discomfort you feel in your thumb/grip.

	Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree
1. My grip felt secure off the floor	1	2	3	4	5
2. My grip felt secure in the second pull	1	2	3	4	5
3. I felt powerful	1	2	3	4	5
4. I felt fast catching the bar overhead	1	2	3	4	5

Visual analogue scale (Closed hand grip)

No pain Unbearable pain

Appendix 7: *Kinovea analysis steps.*

1) Import video into the kinovea 0.8.15 software available on PC
2) Play the video until one frame prior to the BB leaving the ground as it begins to flex
3) Use the zoom tool to zoom into the reflective marker on the BB
4) Right click on the marker and selection the option "track path"

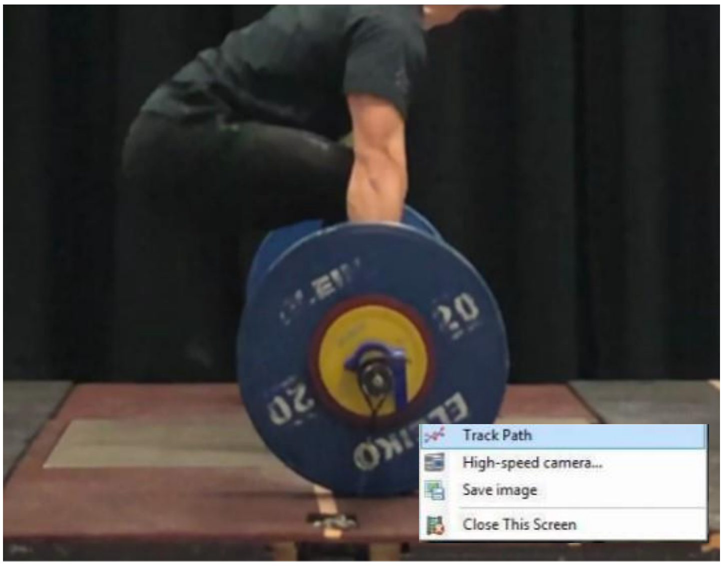

Figure 12. *Bar path tracking.*

5) Insert a stopwatch into the video and right click to start the stopwatch at the same frame as step 2

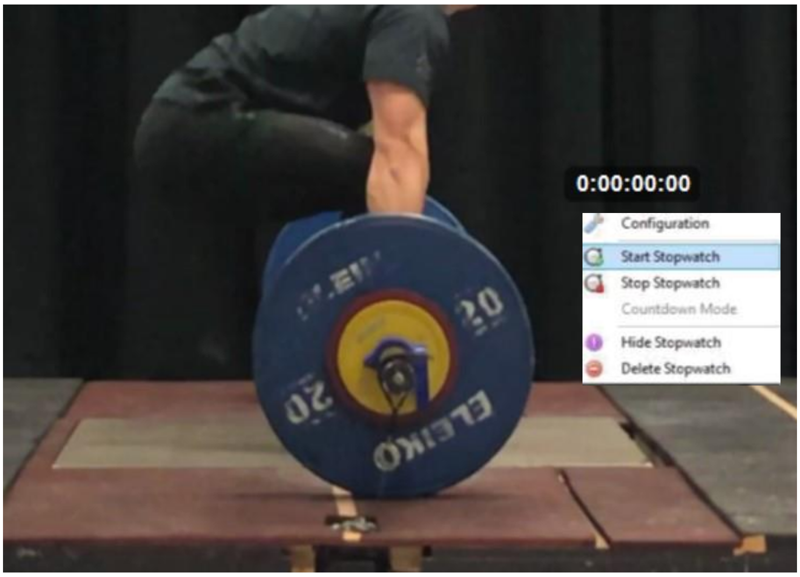

Figure 13. *Syncing the stop watch with the bar path.*

6) Play the video in slow motion to develop a bar path. Manually adjust if required.

7) Once the bar path is adequate, click “end path” at the end of the line.
8) Right click on the line and click “configure path” and change the line thickness to a thin line.

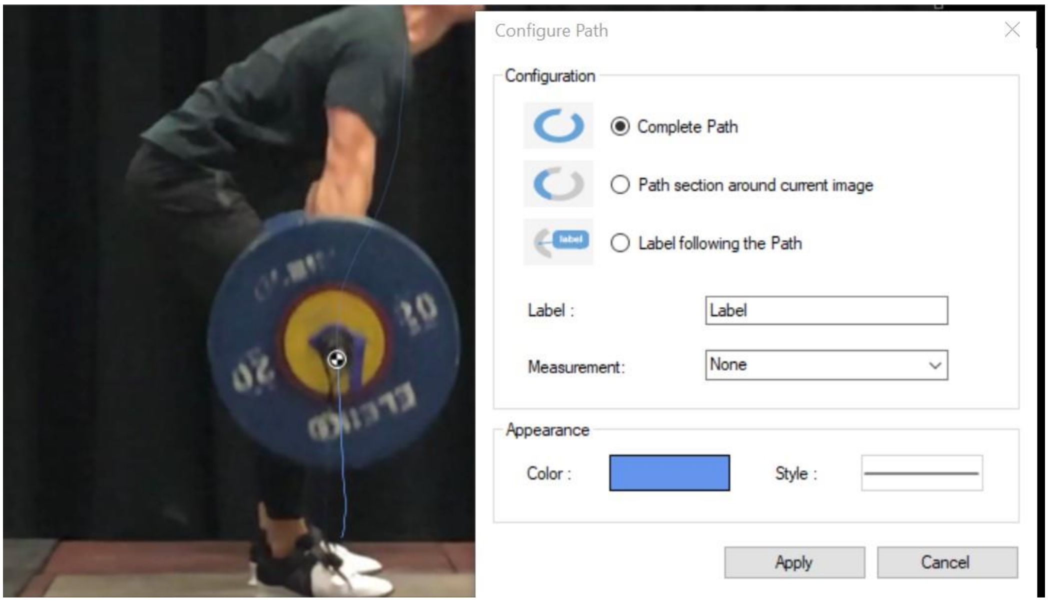

Figure 14. *Configuration of the bar path line.*

9) Click the “line” function to insert a line between the two points of calibration on the platform.
10) Right click on the line and calibrate it to the known length.

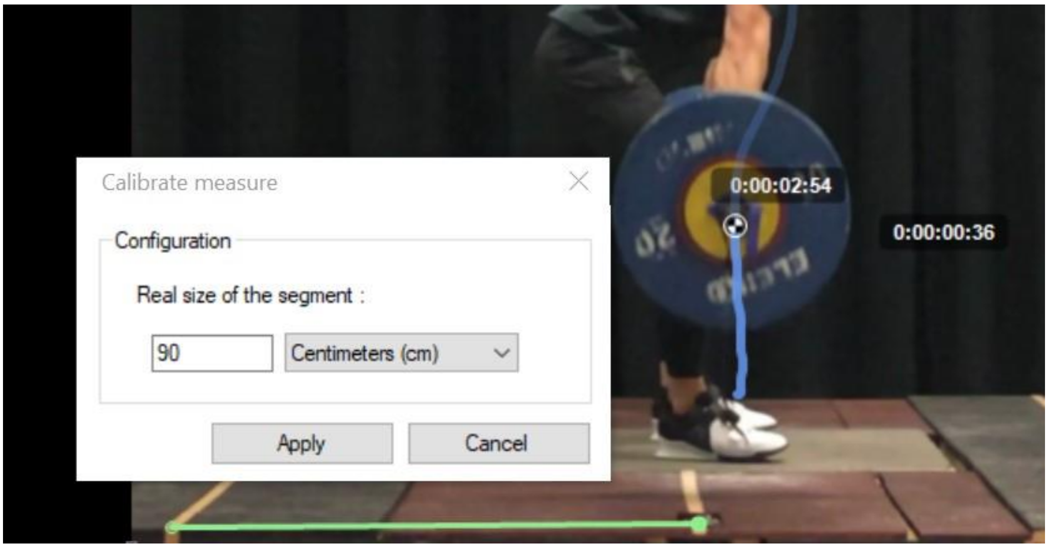

Figure 15. *Calibration of the line.*

Dx2 (the start position to the beginning of the second pull) is measured through the following steps:

1) Play the video until the start of the second pull. To increase accuracy, use the trajectories from the exported excel file and match the time and distance coordinates with the video. If more than one-time reference exists, use the median time point.
2) Using the angle function, draw a 180-degree angle and line it up with the starting position frame.
3) Using the line function, draw a horizontal line from the start of the second pull to the 180-degree line.

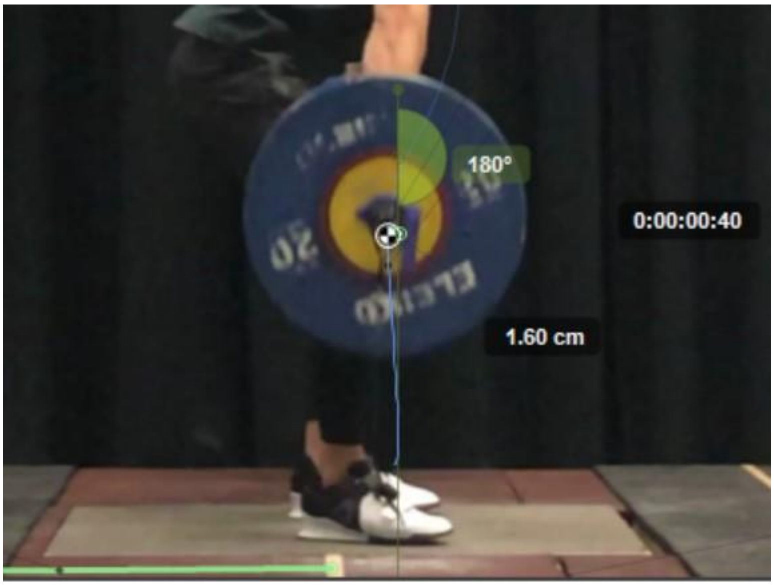

Figure 16. *Measuring Dx2.*

DxV (the start of the second pull to the most forward position) is measured through the following steps:

1) Play the video until the BB is at its most forward position after the second pull. To increase accuracy, use the trajectories from the exported excel file and match the time and distance coordinates with the video. If more than one-time reference exists, use the median time point.
2) Using the angle function, insert two 180-degree angles to line up with the start of the second pull and the most forward position.
3) Using the line function, draw a horizontal line to connect the two angles together. To ensure the line is horizontal, use the angle function to insert a 270-degree angle on top of the line.

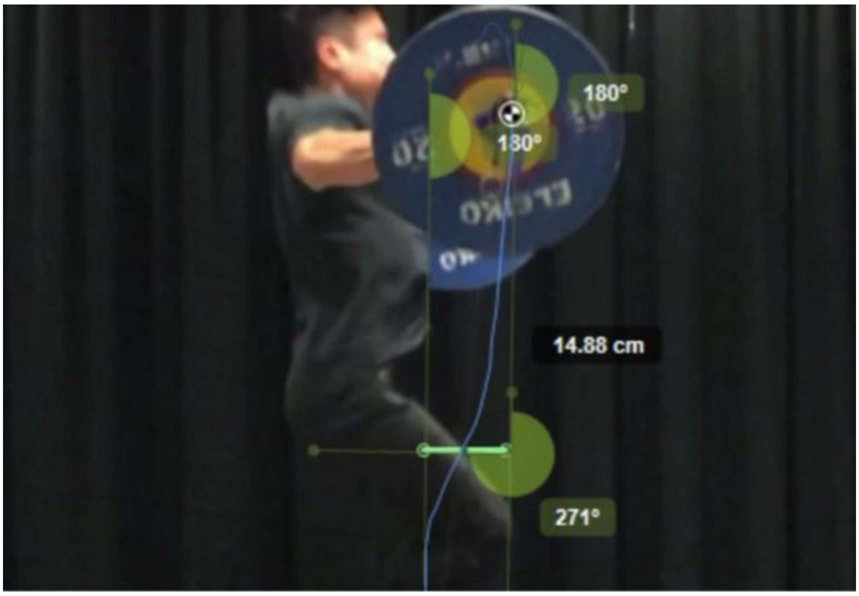

Figure 17. *Measuring DxV.*

DxT (the start position to the catch) is measured through the following steps:

1) Play the video until the BB is at the final catch position before the participant begins to rise from the catch. To increase accuracy, use the trajectories from the exported excel file and match the time and distance coordinates with the video. If more than one-time reference exists, use the median time point.
2) Using the angle function, insert two 180-degree angles to line up with the starting position and the catch position.
3) Using the line function, insert a horizontal line to connect the two 180-degree angles. To ensure the line is horizontal, use the angle function to insert a 270-degree angle on top of the line.

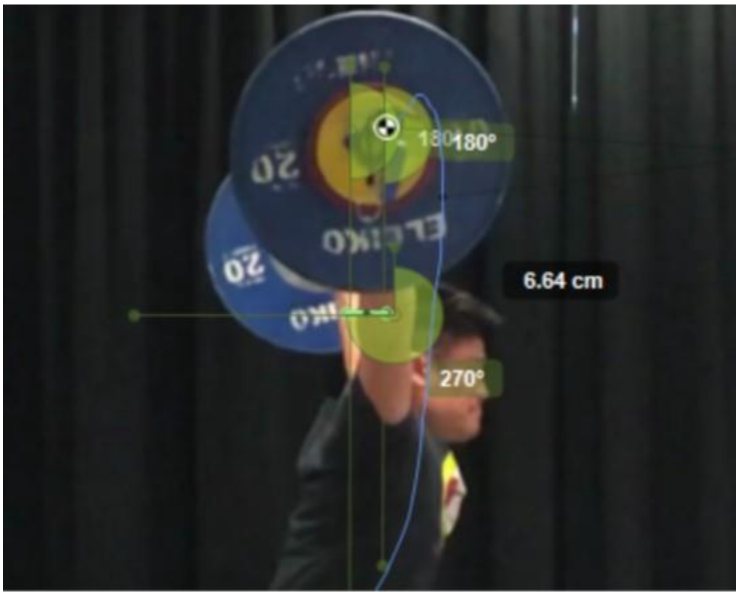

Figure 18. *Measuring DxT.*

DxL (the catch to the most forward position) is measured through the following steps:

1) Maintain the frame where the participant has caught the bar before standing up. . To increase accuracy, use the trajectories from the exported excel file and match the time and distance coordinates with the video. If more than one-time reference exists, use the median time point.
2) Use the same two 180-degree angles previously inserted but move the one lined up with the starting position toward the most forward position.
4) Using the line function, draw a horizontal line to connect the angles together. To ensure the line is horizontal, use the angle function to insert a 270-degree angle on top of the line.

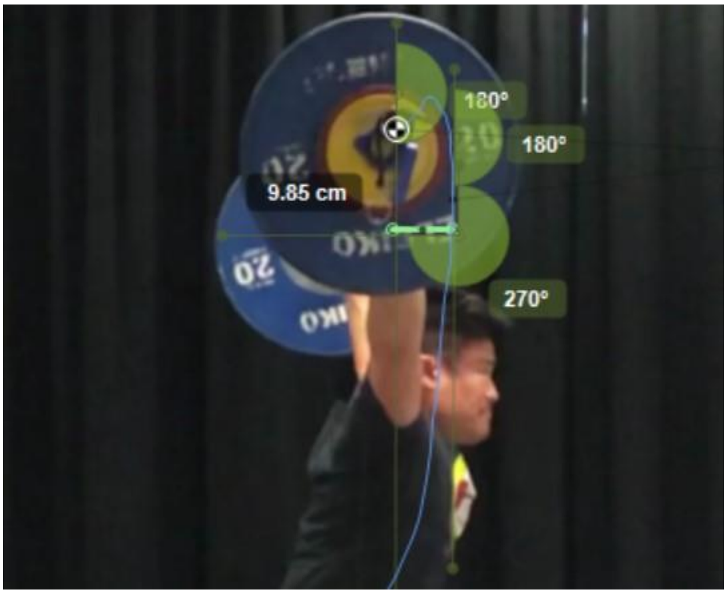

Figure 19. *Measuring DxL.*