THE EFFECTS OF CESSATION OF SUPPLEMENTARY ISOKINETIC AND ISOTONIC TRAINING ON STRENGTH AND BIOMECHANICAL VARIABLES IN STATE – LEVEL WEIGHTLIFTERS

by

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Dissertation submitted in partial fulfilment of the requirements

for the degree of Bachelor of Health Sciences (Honours)

(Exercise and Sports Science)

JUNE 2016

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisor, Dr. Shazlin Shaharudin for her assistance, continuous guidance and advice in planning and execution throughout this research project.

Special thanks are also extended to Ms. Mazuin and Mr Mohamad Faiz for all the opinions and useful suggestion given regarding the study. This study is financially supported by USM Short Term grant (304/PPSP61313152). I also indebted to the Madam Jamaayah Meor Osman for her technical assistant in the laboratory.

I also wish to thank the staff of the Sport Science Unit, Universiti Sains Malaysia, especially Madam Norlida Azalan, Madam Nurfadhilah Ain and Mr Mohd Nawawi Yasin for helping me with the laboratory work and giving support to me during the process of data collection.

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ABSTRAK

PENGENALAN: Hingga ke hari ini, masih kurang lagi kajian tentang perbandingan kesan susulan antara kesan latihan tambahan isokinetik dan latihan isotonik terhadap pemboleh ubah kekuatan dan biomekanik dalam kalangan atlit angkat berat peringkat negeri. Dalam kajian pemboleh ubah biomekanik otot rangka *rotator cuff*, kebanyakan kajian dijalankan ke atas golongan *sedentary* dan sukan-sukan raket berbanding atlit angkat berat. **OBJEKTIF:** Kajian ini dijalankan untuk membandingkan kesan susulan selepas sebulan tamat 24 sesi latihan tambahan isokinetik (IT) dan latihan isotonik (TON) terhadap tindak balas pemboleh ubah biomekanik otot rangka *rotator cuff* dikalangan atlit angkat berat peringkat negeri. **KAEDAH:** Seramai sembilan belas orang peserta disuaipadankan jantina dan berat, diagihkan kepada kumpulan IT dan kumpulan TON. Kedua - dua kumpulan menjalani 24 sesi latihan tiga kali seminggu selama lapan minggu dengan menggunakan tiga posisi yang berlainan. Intensiti latihan ditingkatkan secara berperingkat dari segi jumlah pengulangan dalam satu set dan jumlah set. Sebulan selepas latihan tambahan ini tamat, para atlit akan menjalani ujian susulan untuk melihat kesan susulan selepas latihan. Analisis kinematic 2D dijalankan terhadap kelajuan barbell dalam fasa 'second pull' dan 'turnover' ketika 1-RM power clean dan power snatch dijalankan. Bagi kumpulan IT para atlit perlu duduk di atas kerusi bagi menjalani latihan diatas mesin isokinetik dengan berpandukan buku panduan yang telah disediakan. Posisi kerusi dan

‘dynamometer’ akan di setkan pada sudut yang tertentu bergantung kepada keselesaan atlit. Selepas itu, para atlit perlu melakukan 2 set dari 12 ulangan dan sudut kelajuan ditetapkan pada $120°.s^{-1}$. Sementara itu, bagi kumpulan TON, mereka perlu menggunakan *dumbbell* dan melakukan latihan dengan pergerakan yang sama seperti latihan isokinetik dengan sedaya upaya yang mereka boleh dengan kelajuan yang tinggi. **KEPUTUSAN:** Hasil kajian mendapati tiada hubungkait antara masa (selepas ujian 1 bulan) dan program latihan (IT berbanding TON) selepas sebulan tamat dari 24 sesi latihan tambahan terhadap pemboleh ubah biomekanik otot rangka *rotator cuff* di kalangan atlit angkat berat peringkat negeri. Pada masa yang sama, satu perubahan positif yang sama didapati dari sudut pemboleh ubah biomekanik otot rangka *rotator cuff* di kumpulan IT berbanding kumpulan TON dari segi *peak torque.body weight*, *time to peak torque* dan *average power* bagi pergerakan di sendi bahu. Namun, latihan TON adalah lebih baik berbanding dengan latihan IT selepas kesan susulan latihan bagi 1RM (repetition maximum) *power clean* dan *power snatch* dan juga semasa analisis kinematik semasa ujian 1RM. **KESIMPULAN:** Latihan isokinetik berpotensi untuk dijadikan sebagai satu bentuk latihan tambahan dikalangan atlit angkat berat yang berpengalaman bagi meningkatkan prestasi mereka.

The Effects of Cessation of Supplementary Isokinetic and Isotonic Training on Strength and Biomechanical Variables in State – Level Weightlifters

ABSTRACT

INTRODUCTION: To date, no studies have been carried out to compare the effects of cessation of supplementary Isokinetic Training (IT) and Isotonic Training (TON) in strength and biomechanical variables among elite weightlifters. Regarding biomechanical variables of the rotator cuff muscles, most studies were conducted on sedentary population and racket-sports instead of advanced level of weightlifting athletes. **OBJECTIVES:** This study aimed to compare the cessations effects 1 month after they completed the 24 sessions of isokinetic and isotonic supplementary training among state-level weightlifters on biomechanical variables of rotator cuff muscles. **METHODS:** Nineteen participants were gender- and weight- matched and randomly assigned into isotonic training group (TON) and isokinetic training (IT) group. Both groups went through 24 sessions of training programmed three times per week for 8 weeks in three distinct lifting positions. The intensity of training was increased progressively in terms of number of lifting repetitions per set and number of sets lifted. After 1 month of the cessation of supplementary training programmed, the athlete when through a follow-up testing. The 2D-kinematic analysis of barbell velocity was evaluated during the second pull and turnover phases of 1-RM power clean and power snatch tests. In IT group, the participant was allowed to be seated on the chair to perform the training programed based on the guidelines instructions. The position of the chair and dynamometer will be set at the particular angle depends on the participant's comfortability. The participants were asked to perform two sets of 12 repetitions and the angular velocity was set at 120°.s^{-1}. Meanwhile in TON group, they using the dumbbell and perform the exercise with maximum effort (as fast as they can). **RESULTS:** This study revealed that there was no interaction between time (e.g., post- and post1 month-tests) and training programmed (e.g., IT versus TON) was found 1 month after they completed their 24 sessions of supplementary training on biomechanical variables among state-level weightlifters. There was a trend that indicated positive changes in biomechanical variables of IT group compared to TON group in terms of peak torque/body weight, time to peak torque and average power of the external rotation of the shoulder joint. However, the TON training was better compared to IT training after the cessation effects in 1RM (repetition maximum) power snatch and power clean, and also in kinematic analysis during 1RM test. **CONCLUSION:** The isokinetic training program has a potential to be proposed as an additional mode of training among the experienced weightlifters to improve their performance.

CHAPTER 1

INTRODUCTION

Olympic weightlifting is a sport that requires the athlete to lift maximum combined weight lifted during the clean and jerk, and snatch events. Two lifts are currently performed in Olympic competition, the snatch (SN), and clean and jerk (CJ). The SN is performed by lifting the weight from the floor to overhead in one movement, and is more technically demanding (Ho et al., 2014) than the CJ but both begin with similar phases; the first pull, transition, second pull, turnover, catch, and recovery (Narayana et al., 2010). In recent years, there has been mediocre increases in maximum weights lifted during the SN at the international level (Ho et al., 2014).

The SN utilises every major joint and activates a wide array of muscles to accomplish the lift successfully. One primary joint that provides both assistance in the pulls and the catch is the glenohumeral joint (GHJ) (Chen et al., 2012). During the catch and recovery phases of the SN, the shoulders are in full flexion and high ranges of abduction (ABD) are reached. In this position, GHJ stability is the key to a successful lift whereby both dynamic and static stabilizers are required. Many lifts are unsuccessful because the athlete cannot maintain the weight above their head. While there is more to a successful lift than just the upper extremity mechanics and stability, there is the possibility that the Rotator Cuff (RTC) muscles play a crucial role in maintaining GHJ stability and positioning during the Olympic snatch.

The isotonic training has been reported to be equal to or more effective than isokinetic training in which the muscle contractions are similar to the functional movement (Elmquist et al, 1998). Besides, isotonic exercise appears to be the most frequently used training method for injury prevention (Strauss, 1991). Most of the weight lifting training involved isotonic muscle contractions of lifting free weight. For instance, biceps curl and triceps curl are examples of the isotonic training. An isotonic muscles contraction induced the greatest resistance only at the weakest mechanical points of the range of motion (ROM) of the conducted movement. The resistance remains constant throughout the ROM with varied angular velocity of the involved joint (Kovaleski et al., 1995; Smith and Melton, 1981). Nevertheless, there is a problem in weight lifting isotonic exercise, which is, the inability to maintain the angular velocity towards the end of concentric phase, when the bar velocity slows down towards the end of ROM. Hence, the power development might be improved only at the initial segment of ROM (Kraemer and Ratamess, 2004).

In recent years, isokinetic technology has become an important tool for use in the treatment of the shoulder disorder and also in the shoulder performance. Ellenbecker and Davies (2000) state that, the isokinetic dynamometer plays an important role for testing and training of the shoulder complex (Ellenbacker and Davies, 2000). This kind of device can provide accommodating resistance to the movement of a patient. In addition, no matter how much effort is exerted, the movement takes place at a constant pre-set speed, and the isokinetic exercise is relatively safe (Codine et al., 2005). Furthermore, isokinetic training succeeded in enhancing strength and performance of normal subjects by preventing imbalance of the shoulder muscle groups and the performance (Malliou et al., 2004). The emphasis is placed on the testing and training of the internal and external rotation strength of the shoulder.

Other than that, Davies (1984) and Malliou et al. (2004) concluded that isokinetic strengthening was the most effective method of altering the strength ratios of the RTC muscles compared with isolated isotonic training and multi- joint dynamic resistance training. Isokinetic method of training can be used to restore the imbalances of the RTC muscle group. RTC muscle are important to stabilize the shoulder joint during lifting. A part from that, shoulder joint disability which is widespread among weightlifters due to extreme overhead shoulder flexion may be improved by balancing the strength of the RTC muscles group (Calhoon and Fry, 1999). Hence, Kang and friends (2013) agreed that the balance of RTC muscles' strength is critical especially when athletes need to maintain a heavy load above their head for a few seconds such as immediately after the jerk motion.

Furthermore, isokinetic training mode applied the principles of accommodating resistance following the amount of force exerted. This will allow a constant velocity across the full ROM of the involved joint to be reached by the athlete and further, avoid the disparaging effect of deceleration phase in isotonic movement. Therefore, a maximal effort can be experienced during isokinetic contraction because the maximal load is applied throughout the whole ROM (Kraemer & Ratamess, 2004).

Despite of the listed benefits of isokinetic training, no studies have been carried out to compare the cessation effects of Isokinetic training (IT) and Isotonic training (TON) on strength and biomechanical variables on rotator cuff muscle among experiences weightlifters. Most of the studies only addressed a single movement of either eccentric or concentric muscle contraction. Furthermore, in biomechanical variables of the RTC, most studies were conducted on sedentary population and racket – sport compared to advanced level of weightlifters whereby the adaptation to strength training is different compared to novice lifters. Hence, the present study is warranted.

1.1 OBJECTIVE OF THE STUDY

General Objectives:

1) To compare the effect of cessation of supplementary Isokinetic and Isotonic training on strength and biomechanical variables in state – level weightlifters.

Specific Objectives:

1) To compare the effects of supplementary training cessation on 1RM power clean and power snatch.
2) To compare the effects of supplementary training cessation on 2-D kinematic of barbell velocity.
3) To compare the effects of supplementary training cessation on isokinetic variables.

1.2 RESEARCH HYPOTHESIS

H_{o1}: There is no significant difference in performance outcomes (1RM-repetitive maximum of power clean and power snatch, barbell velocity during second pull and turn over phases) after 1month cessation of isokinetic and isotonic training.

H_{A1}: There is significant difference in performance outcomes (1RM-repetitive maximum of power clean and power snatch, barbell velocity during second pull and turn over phases) after 1month cessation of isokinetic and isotonic training.

Ho_2: There is no significant difference in shoulder joint isokinetic variables (peak torque/body weight, time to peak torque and average power) after 1month cessation of isokinetic and isotonic training.

H_{A2}: There is significant difference in shoulder joint isokinetic variables (peak torque/body weight, time to peak torque and average power) after 1month cessation of isokinetic and isotonic training.

1.3 OPERATIONAL DEFINITIONS

Isokinetic Training Programmed: The 1st interventional group with 24 training sessions (three times per week for eight week).

Isotonic Training Programmed: The 2nd interventional group with 24 training sessions (three times per week, for eight week)

Biomechanical variables: 2D analysis of barbell velocity during second pull and turn over phase at sagittal plane and shoulder joint concentric internal and external rotation isokinetic variables such as Peak Torque/Body Weight, Time to Peak Torque and Average Power measured at 45° shoulder abduction with angular velocity of $120°.s^{-1}$.

Muscular strength and power: Measurements of relative 1-RM power clean and power snatch (maximal weight lifted per body weight).

1.4 SIGNIFICANCE OF THE STUDY

It is hoped that the results of the present study can be applied by the weightlifting coaches and athletes in order to enhance their performances through supplementary training focusing on rotator cuff (RC). Furthermore, the knowledge gained from this study may shed some light regarding the adaptations of musculoskeletal following different modes of training among advanced level of weightlifters.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION OF WEIGHTLIFTING

Weightlifting is a dynamic strength and power sport in which two multi – joint, whole body lifts are performed in competition; the snatch, and clean and jerk (Storey and Smith, 2012). Weightlifting is an athletic discipline in the modern Olympic programmed in which athlete attempts a maximum – weight single lift of a barbell loaded with weight plates, which required the explosive power from the athlete to perform. The sport is often referred to as Olympic (style) weightlifting since it is contested in the Olympic Games. Weight lifting is characterized by predominantly rapid movement, often through a great range of movement (Hamill, 1994).

During the performance, of the two competitive lifts, the snatch and the clean and jerk, weightlifters are required to generate extremely high peak forces and contractile rates of force development and, consequently high peak power outputs and contractile impulses (Storey and Smith, 2012). Furthermore, weightlifting competitions are required an essential skill to transmit physical output effectively to the barbell and support the barbell over the head. Moreover, the failure in attempting in a real competition usually occurs when the barbell falls either in front of or behind the weightlifter during the catch phase due to an incorrect amount of pull force or poor catching techniques (Chiu et al., 2010). Thus, it is important in weightlifter to improve their athletic performance by increasing muscular strength, power and speed, hypertrophy, local muscular endurance, motor performance balance and coordination (Kraemer and Ratamess, 2005).

2.2 HISTORY OF WEIGHTLIFTING

In the International Olympic Committee (John, 2015), stated that, weightlifting was on the program of the Games of the I Olympiad in Athens in 1896, (included in the gymnastics program). The sport was not staged at the Games in Paris 1990, but was re-included for the Games in St. Louis in 1904 (in the athletic program), then disappeared again in 1908 and 1912. Since the Games of the VII Olympiad in Antwerp in 1920, it has been on the program of each edition. Women's weightlifting made its debut on the Olympic program at the Games of the XXVII Olympiad in Sydney in 2000. In addition, John also stated that, there were several evolutions in the number of events that had been changes years after years. In 1896 – 1904, there was only 2 events. Starting from 1920 – 1936, the events increase from 2 events, to 5 events, in 1948 there were 6 events, 1552 – 1968, 7 events, 1972 – 1976, 9 events, and 1980 – 1996, 10 events. From 1896 until 1996, the participations were only males. Starting from 2000 – 2016, there are 15 events which is 8 men's and 7 women's. In brief, weightlifting has been introduced since in the Ancient Olympic Games and continue compete in Modern Olympic Games, until now by involving two main major lifts; the snatch and the clean and jerk lifts.

In the early part of the 20th century, the United States nation was dominated in weightlifting competition (Chiu, 2009). Nevertheless, in 1950s till 1970s, the Union of Soviet Socialist Republic (USSR) was the most successful country. Later on, in between the 1970s and 1992, the USSR and Bulgaria shared the dominant position in weightlifting. Apart from that, the elite competitors competing at international competitions increased due to dissolution of the Soviet Union in 1991. Moreover, since 1996, China, Middle East Country, and South America have fielded competitive teams and competed for top position in the Olympics. Eventually, till 2007, there are 167 countries are recognized by the International Weightlifting Federation (Chiu, 2009).

In spite of this, the first event of female weightlifting competition was introduced on 1987 in World Weightlifting Championship (Gourgoulis et al., 2002). Apart from that, in Olympic Games, not until 2000 Olympic Games in Sydney, the female competitors were participated in the weightlifter's contest either in snatch and clean and jerk, at an Olympic event (Hoover et al., 2006). In a nutshell, the weightlifting competitions are a very popular competition nowadays and not only men involved in this particular competition, but a women contestant also involve in weightlifting competition.

2.3 TECHNICAL AND COMPETITION RULES

According to International Weightlifting Federation (IWF) Technical and Competition Rules (2009), there are two types of lifts, the snatch, and the clean and jerk. Both lifts must be executed with two hands. A maximum of three attempts is allowed in each lift. Subsequently, the athletes have to compete in the categories specified in the rules depends on their bodyweight either in men or women competitions. Besides, the IWF recognizes three age groups which are, Youth groups (up to and including seventeen years of age), Junior groups (up to and including twenty years of age), and Senior groups. In Olympic Games, sixteen years old is the minimum age for men and women to participate while in the Youth Olympic Games, sixteen and seventeen is the participation age.

2.3.1 The Snatch

The snatch requires the weight barbell to lift from the floor (using a wide grip) to an overhead position in one continuous movement (Storey and Smith, 2012). The first pull is initiated when the lifter extends their knees to raise the barbell off the platform to a position just below knee level. A transition period (a.k.a. double knee bend) follows whereby the knees are re-bent and are moved under the barbell whilst the lifter's trunk is moved to a near vertical position (Enoka et al., 1988). The double - knee bend allows the lifter to take advantage of a stretch – shortening cycle during the subsequent second pull (Sands et al., 2006).

The second pull requires the lifter to maximally accelerate the barbell by simultaneously shrugging the shoulders and extending the hips, knees and ankles. During the performance of near maximal to maximal full snatch attempts, the vertical velocity of the barbell during the second pull can range between 1.65m.s-1 and 2.28m.s-1 (Akkus et al., 2012). Furthermore, during submaximal attempts and snatch – related movements such as power snatch, barbell velocities may exceed 3.00m.s-1 (Winchester et al., 2009). As the barbell rises in the vertical plane to 62 to 78 percent of the lifter's height, the lifter begins to pull their body underneath the barbell which is known as turnover phase (Chiu et al., 2010). The lifter then catches the barbell in a straight – arm overhead position whilst flexing at the knee and hip into a full squat position. The lifter then 'recovers' out of the full squat to a standing position whilst maintaining the barbell overhead. The duration of effort from the start of the first pull until the competition referees signal a successful lift is in between 3–5 seconds. Each athlete is entitled to three snatch attempts in competition.

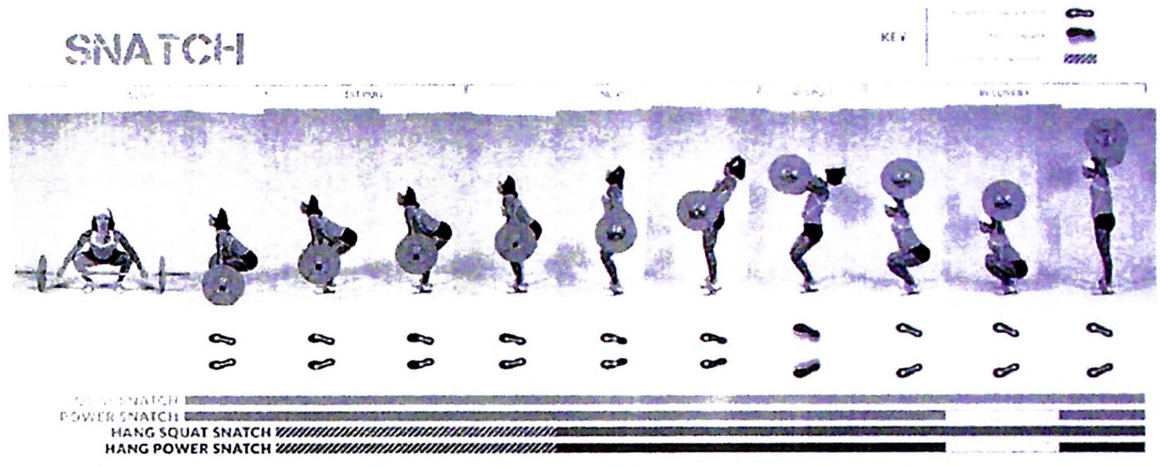

Figure 2.1 The Snatch Phase (PushPress.com)

2.3.2 The Clean and Jerk

The clean and jerk is a two-part lift that enables heavier loads (18 – 20 % greater) to be lifted than during the snatch. The clean requires the barbell to be raised from the floor (using a shoulder width grip) to the front of the shoulders in one continuous movement. There are six phases of the clean. The mechanical principles behind the first three phases (first pull, transition / double knee bend and second pull) are the same as those of the snatch. During the second pull of near maximal to maximal attempts clean, the vertical velocity of the barbell can range from $0.88 m.s^{-1}$ to $1.73 m.s^{-1}$ (Garhammer, 1991). However, during submaximal attempts and clean – related movements such as power clean, barbell velocity may exceed $2.50 m.s^{-1}$ (Cormie and Winchester et al., 2007). Drechsler (1998) stated that, as the barbell rises in the vertical plane to 55 – 65 percent of the lifter's height, the lifter initiates the turn over phase. The lifter then catches the barbell on their shoulder and descends into a full squat position. The lifter then recovers from the full squat, position to prepare for the jerk.

Apart from that, the jerk also has six phases; (i) start phase, (ii) dip phase, (iii) jerk drive phase, (iv) unsupported split under the bar phase, (v) supported split under the bar phase, and (vi) recovery phase. During the start phase, the lifter and the barbell must become motionless. The lifter that begins to dip down by flexing at the knee and hip, with the barbell held across the shoulder. The lowest point of the dip, the lifter makes the transition of the jerk drive where they are required to accelerate the barbell in the vertical plane. During this transition period, the athlete may be exposed to a downward force equivalent to 17 times their body mass. In 1977, Zernicke, Garhammer and Jobe (Zernicke et al., 1977) reported that power outputs during maximal attempt jerk drives range from 2140 watts (W) for a lifter in men's under 56kg class to 4786 W for a lifter in the men's 105 kg+ class. At the completion of the jerk drive, the barbell is vertically driven off the ground. This phase represents the unsupported split under the bar (Garhammer, 1980). Once the lifter's feet are in contact with the ground and the barbell is held overhead with fully extended arms, the lifter is in the supported split under the bar' phase. The lifter must then recover and is required to stand motionless with their feet parallel to one another. The duration of effort from the start of the first pull to the signal of a successful lift is about 8 – 12 seconds. Each athlete is entitled to three clean and jerk attempts in competition.

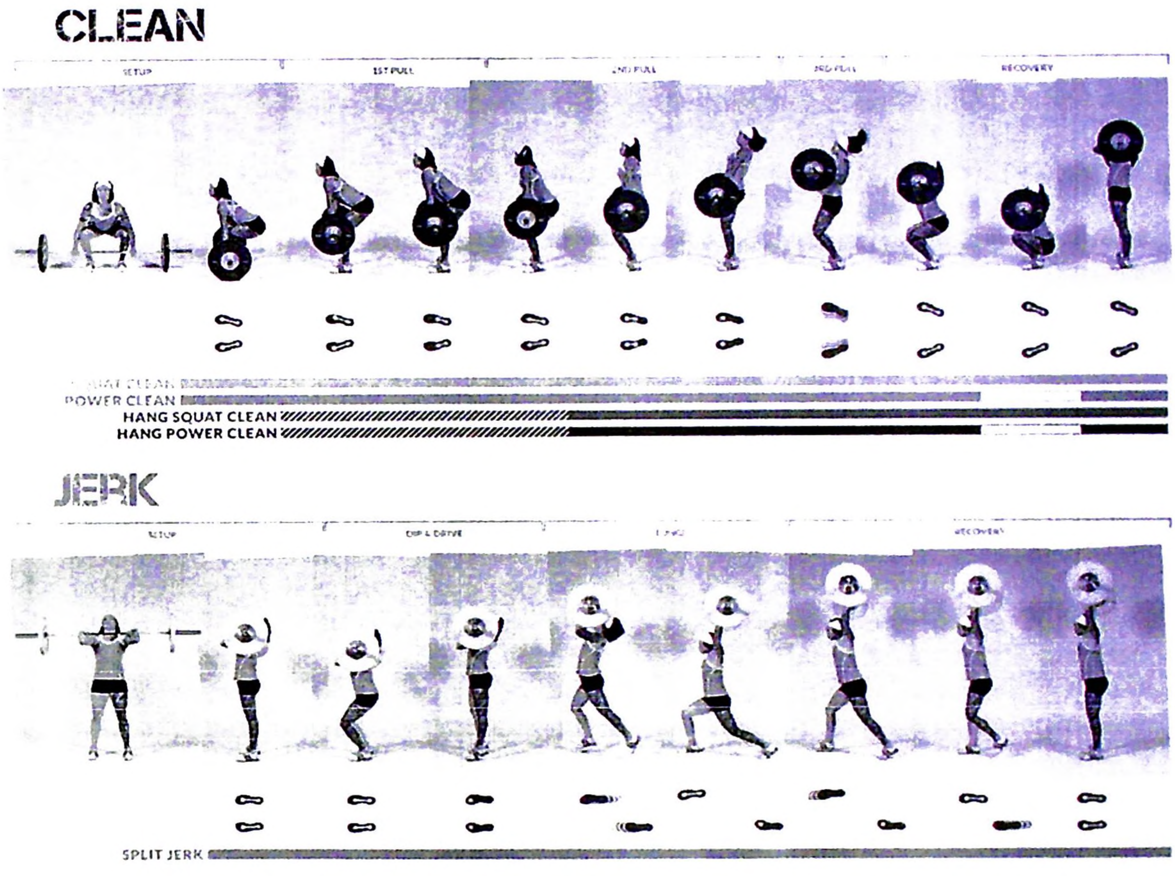

Figure 2.2 Clean and Jerk Phase 1 (PushPress.com)

2.4 COMMON INJURIES IN WEIGHTLIFTING

As weightlifting becomes increasingly popular, safety is a growing concern (Hamill, 1994). The lifts in the sport of weightlifting, emphasize explosive muscular power (Stone et al., 1994), as essential property of many sports (Kujala et al., 1995). In order to specialize the common injury in weightlifting, there are actually three anatomical areas thought to be a high risk of injury for weightlifting, which are also common injuries sites in other sports (Mazur et al., 1993). They are the knee, the low back and the shoulder. Injuries do occur during weightlifting and occur less commonly during supervised strength training than they do during other sporting activities. The most common site of injury during weightlifting is the lower back, and the type of injury mostly encountered is a muscle strain (Mazur et al., 1993). Injuries are often attributable to improper exercise techniques, improper loading, overtraining, weight room accidents, and unsupervised training (Brown and Kimball et al., 1983). According to Goertzen et al., (1989), muscles injuries were common among most weightlifting and powerlifting approximately 84% injury and that major shoulder or elbow injuries had occurred at some point in the athletes training history in 40% of the participants with the incidence twice as high in the power lifters. Likewise, Raske and Norlin (2002) reported higher injury rates in lifters. Furthermore, in comparing elite weightlifters and powerlifter, weightlifters exhibited higher frequency of low back and knee injuries whereas, shoulder injuries were more prominent in power lifters (Raske and Norlin, 2002).

2.4.1 Shoulder Injuries

Shoulder has a high risk of injury for weightlifting due to its anatomical structure. Flexing the shoulder into an extreme overhead position increases the risk of injury (Neviaser, 1993). As a result, instability of the shoulder joint has been reported in weightlifters (Gross et al., 1993). In weightlifting, missed lifts sometimes involve dropping the weight behind the lifter. Such as motion, result in extreme external rotation and flexion of the shoulder (Kulund et al., 1978). This places the shoulder in a vulnerable situation and may increase the rate of shoulder injury (Konig and Biener, 1990).

Experimental studies have demonstrated that; the rotator cuff serves two principle functions at the glenohumeral joint. The first one is generation of torque, necessary for rotation of the humerus on the glenoid, and the second one is compression of the humeral head into the glenoid concavity. This latter function compensates for the lack of inherent bony stability at the glenohumeral joint, serving as the primary stabilizing mechanism for this minimally constrained articulation during the functional range of motion (Warner et al, 1999). Moreover, the stabilizing mechanism of the rotator cuff depends on the integrity of a transverse force couple, which is formed by the anatomical arrangement of the anterior (subscapularis) and posterior (infraspinatus / teres minor), rotator cuff tendons as they insert into the proximal humerus (Lippitt et al., 1993). Futhermore, the concavity compression also resists the superior pull of the deltoid muscle during abduction and provides a fulcrum for concentric rotation of the humeral head on the glenoid (Lippit, 1993).

In addition, the glenohumeral joint reaction force counteracts the sum of all shoulder muscle forces transmitted across the articulation, and its magnitude depends on applied along its length (McMahon et al., 1995). This is due to the rotator cuff and deltoid muscles are the main abductors and rotators at the glenohumeral joint, the magnitude of the joint reaction force during active motion provides an index of the competence of concavity compression (Thompson et al., 1996). Apart from that, there was a previous study that had demonstrated the disruption of the transverse force couple, as occurs in large and massive rotator cuff tears, leads not only to increase translations or subluxation of the humeral head, but also to changes in the magnitude and direction of the reaction force at the glenohumeral joint (Morrey et al., 1998).

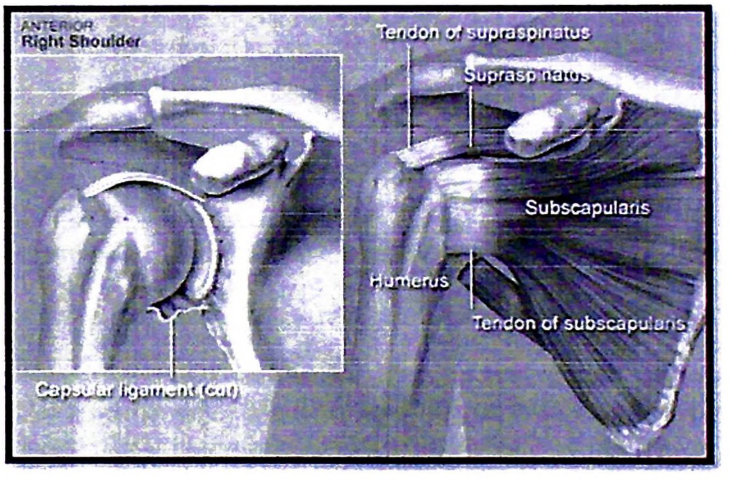

Figure 2.3 Shoulder Joint (WebMD.com)

The rotator cuff (RTC) consists of four muscles; the supraspinatus, the infraspinatus, the teres minor and the subscapularis, and provides stability to the GHJ during arm elevation. If the RTC does not have proper activation patterns during humeral elevation, the humeral head can migrate superiorly causing impingement of the structures that lay under the acromial arch (DeMey, Danneels, Cagnie, & Cools et al., 2012).

elevation, the humeral head can migrate superiorly causing impingement of the structures that lay under the acromial arch (DeMey, Danneels, Cagnie, & Cools et al., 2012).

Repeated superior translation of the humerus can lead to shoulder impingement which can be very debilitating, especially in overhead athletes (DeMey et al., 2012). Shoulder injuries are prevalent in weightlifters and can cause significant amounts of lost training time (Raske & Norlin et al., 2002). Many of the injuries frequently seen in weightlifters' shoulders are from overuse (Neviaser, 1991; Raske & Norlin, 2002), and can occur due to poor technique, poor training habits, joint laxity, and poor muscle recruitment (Myers et al., 2009; Neviaser, 1991; Raske & Norlin, 2002).

During the SN, the RTC is put into unfavorable positions which could cause injuries (Neviaser, 1991; Raske & Norlin, 2002). Few studies have examined muscle activity of the upper extremity during the SN (Chen et al., 2012). Most of these studies have focused on the large muscles around the GHJ. There is currently, no literature on RTC activation during the different phases of the SN.

Experimental studies have demonstrated that the rotator cuff serves two principle functions at the gleno-humeral joint: (1) generation of torque necessary for rotation of the humerus on the glenoid; and (2) compression of the humeral head into the glenoid concavity (Parsons et al., 2002). This latter function compensates for the lack of inherent bony stability at the gleno-humeral joint, serving as the primary stabilizing mechanism for this minimally constrained articulation during the functional range of motion (Bassett et al., 1990).

Termed concavity compression, the stabilizing mechanism of the rotator cuff depends on the integrity of a transverse force couple, formed by the anatomical arrangement of the anterior (subscapularis) and posterior (infraspinatus / teres minor) rotator cuff tendons as they insert into the proximal humerus (Lippitt S, Matsen F et al., 1993). Concavity compression also resists the superior pull of the deltoid muscle during abduction and provides a fulcrum for concentric rotation of the humeral head on the glenoid (Lippitt and Matsen, 1993).

The glenohunieral joint reaction force counteracts the sum of all shoulder muscle forces transmitted across the articulation, and its magnitude depends on the torque generated by the activity of these muscles in moving the upper extremity and resisting loads applied along its length (McMahon et al., 1995). Because the rotator cuff and deltoid muscles are the main abductors and rotators at the glenohumeral joint, the magnitude of the joint re- action force during active motion provides an index of the competence of concavity compression (Thompson et al., 1996).

Furthermore, previous studies have demonstrated that disruption of the transverse force couple, as occurs in large and massive rotator cuff tears, leads not only to increased translations or subluxation of the humeral head, but also to changes in the magnitude and direction of the reaction force at the glenohumeral joint (Morrey et al., 1998). Thus, the degree to which different rotator cuff tear configurations affect the mechanical integrity of the transverse force couple can be studied in terms of their effect on the magnitude and direction of the glenohumeral joint reaction force during simulated active motion.

2.5 BIOMECHANICAL VARIABLES

Previously, study have investigated the biomechanical features associated with technique and performance in the sport of weightlifting (Enoka et al., 1979). The biomechanical variables most related to the mechanics of the barbell (barbell trajectory, velocity, acceleration and power). From these studies, it shown that biomechanical variables can be used to distinguish between lifters of different skill level or between successful and unsuccessful lift attempts (Gourgoulis et al., 2000). In addition, barbell acceleration during lift attempts have received recent attention, partially because barbell acceleration are thought to relate to key aspects of lifting technique and performance (Bottcher and Deutscher, 1999).

Performance and success in the sport of weightlifting is dictated by the mass a competitor can lift under the task constraints and strict rules of the events (Kipp *et al.*, 2012). Given these restrictions, large variations in the lifting technique are generally not to be expected (Kauhanen et al., 1984). Although most lifters use similar technical styles of lifting (Garhammer. 1985), several differences in barbell trajectories and kinematic or kinetic characteristics exist between lifters with diverse experience or skill levels (Baumann et al., 1988).

Kipp et al. (2012) mentioned that, distinct differences in weightlifting biomechanics have been observed between skilled and novice lifters. For instance, Burdett (1982) reported that, greater peak extension motions of the hip and knee for highly skilled world class lifters compared with skilled collegiate lifters during the first and second pull phases. Then, elite weightlifters also extend their knee and ankle joints more rapidly during these phases than do adolescent weightlifters (Gourgoulis et al., 2004).

Furthermore, Kauhanen et al. (1984) reported a significant correlation between the maximal relative (i.e., body mass–adjusted) ground reaction force during the first pull of the clean movement and performance level (i.e., maximal mass lifted). Although ground reaction forces provide knowledge about the overall force-time profile of the lifter-barbell system, the most detailed information about weightlifting performance comes from the combined dissemination of joint kinematics and kinetics (Baumann et al., 1988).

Baumann et al. (Baumann et al., 1988) examined the correlation between the total mass of the lifter-barbell system and internal joint moments. Furthermore, they also found strong to moderate correlations between the lifter-barbell system mass and the overall peak hip and the second peak knee extension moment. Unfortunately, Baumann et al. (Baumann et al., 1988) did not normalize the lifter-barbell system mass to account for weight classes, nor did they normalize the joint moments to account for anthropometric differences. Consequently, it still remains to be determined how biomechanical variables (e.g., joint kinematics or kinetics) relate to weightlifting performance (i.e., body mass–adjusted lift mass).

2.6 ISOKINETIC TRAINING

Nowadays, isokinetic strength of the shoulder is often used by clinicians to objectively assess muscle performance (Dauty et al., 2003). It can help determine a functional-strength profile in orthopaedic patients and athletes suffering from shoulder disorders (rotator cuff over- use, anterior instability, recovery after surgery, peripheral neurological pathology) or assess functional dynamic stability and muscle performance of shoulder musculature in overhead athletes (Edouard P. et al., 2010).

Thus, isokinetic of IR- and ER-muscle strength is currently used to guide diagnosis, therapy, and rehabilitation (Codine et al.,2005). Concentric and eccentric contraction modes are evaluated, (Sirota et al., 1997) in association with the ER:IR ratio, which describes the strength characteristics of the muscles at the shoulder joint (Davies et al., 2004).

Furthermore, the isokinetic training measurement process must be valid and reliable to be meaningful and interpretable (Plotnikoff et al., 2002). The more reliable the measurement the higher the probability of adequate sensitivity to track small but clinically important changes (Impellizzeri et al., 2008).

Many studies indicate that the technical accuracy and reliability of isokinetic instrumentation are very high in measuring torque, work, and power in many joints (Davies et al., 2004). However, given the kinematics of the shoulder joint and its relatively extensive mobility, questions have been raised about the reliability of isokinetic shoulder assessment (Plotnikoff et al., 2002).

Although it is influenced by many factors (mechanical aspects, subjects, joints, etc.) (Chan et al., 1996) the assessment position, including the position of the shoulder (shoulder posture (Kimura IF et al., 1996) and joint-axis alignment (Rothstein et al., 1987) and the position of the body (sitting, supine, or standing and stabilization), appears to be a determining factor (Edouard et al., 2009).

The reliability of ER- and IR-muscle strength measurements is a controversial issue because of differences in the methodological aspects and design of studies (Codine et al., 2005). One of these methodological points is the position used during tests, including the subject's posture (sitting, standing, or supine) and the shoulder posture (in the frontal or scapular plane with 0°, 45°, or 90° of shoulder abduction), which together determine the alignment of the joint axis (Edouard et al., 2009). The influence of the position on measurement reliability is not known (Meeteren et al., 2002).

A second methodological point is the mode of contraction (concentric or eccentric) used during tests and the parameter used to assess IR and ER strength (peak torque or ER:IR ratio).

Isokinetic training able to perform in a variety of positions at different speeds. The complexity of the shoulder and the risk of injury are cited as reasons for limited study of the shoulder during isokinetic activity.

2.6.1 Effects of Isokinetic Training

Isokinetic resistance training is effective training for increasing muscular strength due to high forces produced by muscles, which is contracting at a constant speed through the entire range of joint motion. Isokinetic exercises may be performed concentrically (muscles shorten during contraction) or eccentric (muscles lengthen during contraction) as external forces are applied to the limb. Therefore, these contrasting forms of dynamic resistance exercise allow for application of high muscular loads and consequently, high skeletal loads (Nickols-Ricarhdson et al., 2005). Subsequently, when maintained over a sufficient period, these forms of exercise may afford a means of safety and optimally promoting functional and structural adaptations in bone and muscle tissue (Miller et al., 2006).

Both modes of isokinetic training have been extensively studied in efforts to quantify effects on muscle morphology (Higbie et al., 1996), strength (Dudley et al., 1991) and training transferability to other motor performance task (Enoka, 1996). Bast et al., (1998), stated that, higher internal loading of muscles may be safely applied with the eccentric (~15 – 25 % higher forces) compared with concentric modality, and in young adults, eccentric training may result in greater muscular strength gains (Bast et al., 1998).

2.7 ISOTONIC STRENGTH TRAINING

Strength training (also known as resistance training) is a common component of sports and physical fitness programs for young people, although some adolescents may use strength training as a means to enhance muscle size for improving appearance. Strength-training programs may include the use of free weights, weight machines, elastic tubing, or an athlete's own body weight. The amount and form of resistance used and the frequency of resistance exercises are determined by specific program goals (American Academy of Pediatrics, 2008).

There are several benefits of strength training as obvious goal of getting stronger, strength-training programs may be undertaken to try to improve sports performance and prevent injuries, rehabilitate injuries, and/or enhance long-term health. Strength training has been shown to have a beneficial effect on several measurable health indices, such as cardiovascular fitness, body composition, bone mineral density, blood lipid profiles, and mental health (Faigenbaum and Stricker, 2002). Recent studies have shown some benefit to increased strength, overall function, and mental well-being in children with cerebral palsy (Blundell et al., 2003).

Increases in strength occur with virtually all modes of strength training of at least 8 weeks' duration and can occur with training as little as once a week, although training twice a week may be more beneficial (Flak et al., 1996). Unfortunately, gains in strength, muscle size, or power are lost 6 weeks after resistance training is discontinued (Faigenbaum et al., 2000).

2.8 THE EFFECTS OF CESSATION OF SUPPLEMENTARY TRAINING

Muscular strength is a major determinant of sports performance, both in explosive (Delecluse, 1997) and long- duration events (Saunders et al., 2004). The capacity of the skeletal muscle to generate a high level of force is a complex interplay between several factors, including muscle fiber type (Gollnick & Matoba, 1984), muscle cross-sectional area (Jones et al., 2008), muscle architecture (Aagaard et al., 2001), and neural drive to the muscle (Gandevia, 2001). Resistance training is a safe and effective intervention to improve these determinants and increase muscular strength, whatever age and sex (Falk&Tenenbaum, 1996; Latham et al., 2004; Ratamess et al., 2009).

However, training- induced adaptations are transitory and may disappear when the training stimulus is withdrawn, thus leading to detraining. Detraining has been defined as the partial or complete loss of training-induced anatomical, physiological, and functional adaptations, as a consequence of training cessation (Mujika & Padilla, 2000).

The reasons for such a scenario are numerous in an individual's life, e.g., illness, injury, travel, loss of motivation, or post-season break in competitive athletes. Identifying the kinetics of strength loss once resistance training ceases is important to design successful tapers and return to optimal fitness for competitive athletes, and more generally for the individualization of exercise training prescriptions whatever the characteristics of the population.

Although there is consensus among narrative reviews that training cessation leads more or less rapidly to detraining (Mujika & Padilla, 2000), methodological heterogeneity does not allow to make direct comparisons between studies or to specify the overall