THE EFFECT OF INTER-REPETITION REST DURATION ON KINEMATIC AND KINETIC OF SNATCH

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ABSTRACT

Controlling and manipulation of inter-repetition rest (IRR) could develop diverse levels of fatigue and manifest changes to lifting mechanics. The objective of this study was to examine the effect of IRR on kinematic and kinetic of snatch lifting during multiple set exercise protocol. Fifteen male (n=15) athletes participated in this study (age = 21.0 ± 1.41 years; body weight = 60.82 ± 2.45 kg; height = 165.70 ± 10.88 cm; snatch one-repetition maximum (1RM)/body weight = 0.73 ± 0.117). Session 1 consisted of anthropometric and 1RM determination. Sessions 2-4 involved subjects performing 3 sets x 5 repetitions of 85% 1RM with 10, 30, or 50 seconds of IRR implemented randomly. Joint angle displacement, joint velocity, ground reaction force (GRF), and barbell velocity (BV) were obtained during each protocol using VICON Motion Analysis (100Hz) and AMTI force plate. Repeated measure ANOVA showed significant differences found in ankle, knee and hip joint displacement and joints velocity. The barbell velocity showed a significant effect between IRR, (F (2, 28) = 22.831, $p < .05$), while the maximum vertical GRF showed a significant effect between IRR protocols, (F (1.309, 18.323) = 9.953, $p = .003$). Repeated measure Manova showed a significant effect of IRR on the maintenance of kinematics and kinetic variables across repetition. BV showed a significant effect of IRR on maintenance of velocity across repetition, ($p = .029$). However, no significant effect of IRR was observed on the maintenance of maximum vertical GRF, ($p = .065$). Due to the differences found between IRR protocols, the implementation of IRR may result in an increase or decrease of kinematic and kinetic output due to the different levels of fatigue. The implementation of IRR can help to maintain kinematic and kinetic variables which often are affected by neuromuscular fatigue occurred with continuous repetition.

KESAN TEMPOH REHAT ANTARA ULANGAN (IRR) TERHADAP KINEMATIK DAN KINETIK SNATCH

ABSTRAK

Mengawal dan memanipulasi tempoh rehat antara ulangan (IRR) semasa latihan boleh menyebabkan pelbagai tahap keletihan dan perubahan terhadap mekanik pergerakan snatch. Objektif kajian ini adalah untuk mengkaji kesan IRR terhadap pembolehubah kinematik dan kinetik semasa pergerakan snatch. Peserta (n = 15), (umur = 21.0 ± 1.41 tahun; berat = 60.82 ± 2.45 kg; tinggi = 165.70 ± 10.88 cm; Snatch satu ulangan maksimum (1RM) / berat badan = 0.73 ± 0.117), melakukan 3 set x 5 pengulangan 85% 1RM dengan 10, 30, dan 50 saat IRR diberikan secara rawak. Nilai maksimum anjakan sudut sendi, halaju sendi, daya, dan halaju barbel serta pengekalan pemboleh ubah kinematik dan kinetik merentasi ulangan direkodkan dan dianalisa menggunakan Vicon Nexus (100Hz) dan plat daya AMTI. ANOVA pengukuran berulang menunjukkan perbezaan yang signifikan pada pergerakan sendi pergelangan kaki, lutut dan pinggul serta halaju sendi pada fasa yang berbeza. Halaju barbel menunjukkan kesan yang signifikan antara IRR, ($F(2, 28) = 22.831$, $p < .05$), sementara daya menegak maksimum menunjukkan kesan yang signifikan antara protokol IRR yang berbeza, ($F(1.309, 18.323) = 9.953$, $p = .003$). Manova pengukuran berulang menunjukkan pengaruh IRR yang signifikan terhadap pengekalan pemboleh ubah kinematik dan kinetik sepanjang pengulangan. Halaju barbel menunjukkan kesan IRR yang signifikan terhadap pemeliharaan halaju merentasi pengulangan, ($p = .029$). Walau bagaimanapun, tidak ada kesan signifikan IRR pada pemeliharaan daya menegak maksimum, ($p = .065$). Oleh kerana terdapat perbezaan kinematik dan kinetik yang dijumpai antara protokol IRR, pelaksanaan protokol IRR yang berlainan durasi dapat mengakibatkan peningkatan atau penurunan prestasi kinematik dan kinetik kerana tahap keletihan yang berlainan. Pelaksanaan IRR dapat membantu jurulatih dan atlet untuk mengekalkan pemboleh ubah kinematik dan kinetik semasa latihan snatch yang sering dipengaruhi oleh keletihan neuromuskular yang berlaku akibat daripada pengulangan berterusan semasa latihan.

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ABBREVIATIONS

10s	Ten Second Rest Duration
1RM	One Repetition Maximum
30s	Thirty Second Rest Duration
3D	Three Dimensional
50s	Fifty Second Rest Duration
ACSM	American College of Sports Medicine
AJ	Ankle Joint
AJA	Ankle Joint Angle
AJV	Ankle Joint Velocity
ANOVA	Analysis of Variance
ATP	Adenosine Tri-Phosphate
BV	Barbell Velocity
EMG	Electromyogram
FP	First Pull Phase
GRF	Ground Reaction Force
HJ	Hip Joint
HJA	Hip Joint Angle
HJV	Hip Joint Velocity
IRR	Inter-Repetition Rest
KJ	Knee Joint
KJA	Knee Joint Angle

KJV	Knee Joint Velocity
m/s	Meter Per Second
MANOVA	Multivariate Analysis of Variance
NSCA	National Strength & Conditioning Association
PCr	Phosphocreatine
PFK	Phosphofructokinase
Rad	Radian
Rep	Repetition
SAID	Specific Adaptation to Impose Demand
SP	Second Pull Phase
T1	Transition Phase

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Weight training has been acknowledged to improve strength, power and speed in a number of athletic populations (Manolopous et al., 2016; Schoenfeld, Contreras, Willardson, Fontana & Tiryaki, 2014; Van Roie, Delecluse, Coudyzer, Boonen & Bautmans, 2013; Appleby, Cormie, Cormack & Newton, 2013). Besides improving these physical qualities, weight training also has a significant benefits for power based athletes in terms of increasing muscles mass and also significantly decreasing the risk of injury (Granacher et al., 2016). The ultimate or end goal of an athlete preparation is to maximise their performance during competition and commonly, normal coaches would rather focus on quantity during training rather than quality. It's how many repetition or set you are able to do that matters to them.

Weight training is a common type of strength training for developing the strength and size of skeletal muscles (Keogh & Winwood, 2017). Weight training is one of many type of physical exercise performed to improve muscular strength by

gradually increasing the ability to resist force either through the use of free weight, machines or the person's own body weight. Weight training session are designed to impose increasingly greater resistance, which in turn will stimulates the development of muscle strength (Fleck & Kraemer, 2014). For those who are interested in living a healthy lifestyle, improve health, fitness and also functionality, weight training would serve great benefit to them significantly if done correctly. The introduction of weightlifting movement and its affiliate training regime has become somewhat important and a must in an athletes training programme from a variety of sports. A very popular weight training workout that is widely practised would be the one competed in the weightlifting sport which is the snatch lift. It is a sports in which the athletes would try to lift the heaviest weight as possible in clean and jerk or snatch exercise (Chiu & Schilling, 2005; Hori, Newton, Nosaka & Stone, 2005; Stone, Pierce, Sands & Stone, 2006). The snatch and clean and jerk are known as an explosive exercise. In this study, snatch movement is chosen as the main protagonist where a closer look into snatch movement is studied as a representative of essential weight training for power based sport athletes. Snatch is chosen solely because of its capability as a total body movement exercise which required several body parts to be working in-synch, otherwise there could be a breakdown that might even result in an injury. Apart from that, snatch is an excellent exercise that is commonly used to improve explosiveness and develop overall athleticism (Daws, 2007) which is really beneficial to power based sports athletes.

To look closely into snatch as a sport, it has been around since the 18th and 19th century strong man events and were maintain until present day. Generally, the equipment that was used in snatch is simple and it is the same for all competition involving snatch around the world. The weight used in lifting would be the barbell and

a steel bar or rod in which the steel disk are attached to each end on a revolving sleeve. To describe snatch in one movement would be simply saying it's just like picking up an object from the ground above your head. In a proper explanation, the snatch technique is when the barbell is required to be lifted from the ground in a static position to a straight arm overhead position in one continuous motion and it can be considered as the most technical part in a weightlifting competition (Gourgoulis, Aggelousis, Mavromatis & Garas, 2010). Snatch technique has long been specified into several phases and position to help with coaching instruction and cues that could help to pin point the exact critical and important variables during the lift (Campos, Poletaev, Cuesta, Pablos & Carratala, 2006; Gourgoulis et al., 2002; Gourgoulis, Aggeloussis, Garas & Mavromatis, 2009). However, although established, there seems to be slight different and inconsistent definition of the phases and position that are being used across literature (Bai, Wang, Zhang, Ji & Wang, 2008; Bartonietz, 1996; Campos et al., 2006; Derwin, 1990; Gourgoulis et al., 2002; Medvedev, 1988; Takano, 1993). For the purpose of this research thesis, the snatch will be broken down into 4 position and only 3 phases are taken into account for research analysis. Based on the previous literature knowledge, four positions are as follows: the start position, bar reaching knee level, bar reaching hip level (power position) and triple extension (fully extended) position. Three important phases that are being studied in this research thesis would be the following: the first pull, transition and second pull. The start position required the athletes to be in a position where the middle of their foot is in line with the stationary barbell while their hips and knees are flexed and their back are kept at a neutral position (Derwin, 1990; Stone et al., 2006; Takano, 1993; Winchester, Porter & McBride, 2009).

The first pull phase is a phase where the barbell movement is initiate from a stationary state off the ground. This is a position where although the athletes back is

held in a neutral position, the knee would predominantly extend and together with the hips will contribute to overcome the stationary barbell inertia (Bartonietz, 1996; Hydock, 2001). The phase is completed when the barbell reach knee level (Bartonietz, 1996; Garhammer, 1991; Hydock, 2001). In short, the first pull phase is from the barbell lift-off until the first maximum knee extension (Gourgoulis, Aggeloussis, Mavromatis & Garas, 2000). The transition phase then take place and subsequently began with movement from knee extension to flexion to reach the power position where the heel, hips and shoulder are inline (Tysz, 2010) where the barbell reach the height of the hips, which is required to create a vertical force through the legs for second pull (Bartonietz, 1996; Hydock, 2001; Stone et al., 2006). In simple words, the transition phase could be describe as a movement from the first maximum knee extension until the first maximum knee flexion (Gourgoulis et al., 2000). The second pull phase happens from the first maximum knee flexion until the second maximum extension of the knee (Gourgoulis et al., 2000). When the second pull phases is in command, a coordinated fast knee and hip extension, with plantar flexion occurred and resulted in a position where the lower limb joints reaching full extension and successfully generate and transfer power to the bar in order to lift it overhead (Hydock, 2001; Stone et al., 2006). During this point, while reaching the end of the second pull phase, the barbell reaches its peak velocity before peak displacement (Hydock, 2001). This research thesis only used the data taken until second pull phase. However, the snatch movement proceed further towards the turnover phase where the athletes will subsequently move his/her body in a downwards position and will quickly try to go under the barbell to adopt the catch position (Hydock, 2001). The catch position is a position where the athlete arms are extended above head and be in a similar position as an overhead squat. The weight of the barbell is rested on the extended hand before finally the athletes proceed to complete the lift and finish it

off standing in a fully recovered position (Bartonietz, 1996; Hydock, 2001; Stone et al., 2006). Ultimately, the biggest and number one objective of a weightlifter or an athletes trying to do snatch is to accomplish a lift with external load comprising of the bar and weighted weight off the ground to a fully extended overhead position in one continuous movement (Garhammer, 1980; Gourgoulis et al., 2009; Wang, 2009). In competition, weight are lifted near or above athletes personal best lift thus there is a very little room for error. Such that, it is important for body position to be precisely good and the coordination of joint displacement at different phases of the snatch lift must be in excellent execution to ensure effective force production that is enough to lift the barbell (Garhammer, 1980; Garhammer, 1985; Krol, 2001; Markovic & Sekulic, 2006; Shetty, 1990).

Snatch is known as a strength based movement which demonstrate power and technique, where the athlete change the barbell position from the ground to the overhead position while trying to lift a maximum weight in a single lift possible. This movement includes the whole body muscle power usage during its execution. The whole lower kinematic and kinetic chain is in works trying to complete this movement. Weightlifting performance such as snatch is strongly dependent on explosive strength, technique and flexibility (Ikeda et al., 2012). The minor muscle are also playing its important role as stabilizer in snatch which is categorise as a full body exercise. As a keynote, the lower extremities play a very crucial part in weightlifting especially in snatch routine. The reason is, it does not only start the initial movement but also directing the motion of the barbell and force produce for the movement. This is where the concept of summation of forces by limbs in biomechanics are in action by producing a greater force output as a product to lift the barbell. The different parts of human body combined their forces while the person is moving or trying to move and object. Few

difference parts of the bodies will move and act together to maximise the force. Theoretically, force summation happens when all the body parts that involved moves simultaneously starting from the strongest and lowers body part for example the thigh and trunk followed by the smaller and weaker extremities. This will result in successive force summation (Kent, 2006). The lower extremities is the main joints and muscles that are generating forces during snatch and that is why it is really important in this movement. The three important joint that involved during snatch are the ankle, knee and hips joint which at one point in snatch phase will extend maximally during the same time which is also known as the triple extension position.

The triple extension is also referred to as "achieving full extension of the ankles, knee, and hips to produce maximum power." It can also be characterized as the synchronously full extension of the hip, knee and ankle joint. This event will eventually produce the most external power towards the barbell (Kipp et al., 2013). The triple extension is a very important event during the second pull phase of the snatch. This position used entirely the hip joint because of the largest character of musculature around that joint which in the end will be able to produce maximal force towards the barbell during the triple extension point. Explosive movement of ankle, knee, and hip during snatch is an important factor in increasing athletic success. (Kipp, Harris & Sabick, 2013). Movements like snatch used the power produced by triple extension moment to lift heavy loads from the ground explosively above head. These nature of lifts are basically an explosive continuation of flexion and extensions that produced maximal power generation. If used accordingly, these training exercises like snatch are unparalleled in their potential to train and develop athletic power. (Kipp et al., 2013). However, the problem with triple extension is, the power produce during this point will reduced significantly across continuous repetition because of fatigue. The force and

velocity during this point will reduce significantly if the athlete are training continually without rest just to finish their set of repetition. However, this can be overcome with the introduction of inter-repetition rest which will be discussed further in this study.

Snatch performance is closely related to the kinematic and kinetic pattern of the ankle, knee and hip joint. Performance and achievement in the snatch are critically indicated by the mass an athlete can lift under the stress and strict competition rules of the events competed in the Olympic weightlifting. Given the rules they need to follow, large variation in the lifting technique is generally not to be expected (Kauhanen, 1984). Lower body power development plays a very important role in developing the athletes overall performance in power based sports that required the execution of the triple extension (ankle, knee and hip) movement (Baker & Nance, 1999; Comfort, Udall & Jones, 2012; Hori et al., 2005; Newton & Kraemer, 1994). It is known that a vast majority of sports nowadays that require the explosive performance of the triple extension movement that is sprinting, jumping and rapid change of movement, it has become of utmost important that the coach are able to provide their athletes with a training method that will allow their athletes to produce the best and optimum output of muscular power that could be transfer to sports performance. There is a lot of training method that develop and trains the triple extension exist out there, it is up to the coach and practitioner to select the best and optimal training stimulus for their athletes. Snatch is a very great example in this case.

Why snatch? Why not other exercise? Snatch is a very complex movement to begin with and it does not even justify why athletes need to used it as a tool to improve their athletics performance. However, a numbers of studies has been conducted in finding the similarity between snatch and vertical jump. During a study that compared

the difference between force produced during a vertical jump and hang snatch, the researchers stumble upon a similar values for both maximum and time-to-maximum force and power. Based on these findings, the researcher concluded that the Olympic lifting might enhance coordination between muscles, power and the capability to rapidly generate force (Canavan, Garrett & Armstrong, 1996). Athletes in power and strength sports such as rugby, football or track & field often use various types of weight training for power, speed and strength exercises in their training regime. Weight training is a beneficial training method to be adapted by power-strength based sports such as rugby, sprinting, jumpers, throwers, football and also basketball players as this type of sports emphasize on the maximum power output and also the optimum use of the triple extension joint. Carlock et al., (2004) goes another miles by confirming what Canavan had done that the power produce during vertical jump were strongly related to the abilities of elite Olympic lifting athletes. This study provides another positive reason to use Olympic lifting like snatch because peak power production is important for success in explosive sports such as jumping and sprinting (Carlock et al., 2004). Another research also shown that the ground reaction force (GRF) during vertical jump are similar as during snatch and this further suggesting snatch effectiveness in improving the force output of an athletes (Garhammer and Gregor, 1992). There are other few studies that investigate the benefit of snatch lifting compared to other resistance based training to improve the athletics performance (Garhammer, 1993; Hoffman, Cooper, Wendell & Kang, 2004; McBride, 1999). Based on the nature of what snatch could provide, snatch lifting would be the most appropriate training method to be applied because of it positive feedback. In a simple word, the snatch movement involved the triple extension joint which are widely used and are a major contribution towards a varieties of sports especially the power based sports athletes towards

performance. If an athlete can snatch heavy load, it means that his or her force production is high and the power production will also be high. That will means that he or she is faster and stronger. This is one of the reason why snatch is chosen as the movement in this study.

Past research has reported that training that includes plyometric exercise (De Villarreal, Requena & Newton, 2010; De Villarreal et al., 2009; Markovic, 2007; Ebben et al., 2010; Miller et al., 2006; Ebben, Suchomel & Garceau, 2014; Rimmer & Sleivert, 2000), sprints (Rimmer & Sleivert, 2000; Zafeiridis et al., 2005; Spinks et al., 2007; MacDougall, Hicks, MacDonald, et al., 1998), whole body movement (vibration) (Marin & Rhea, 2010; Cardinale & Bosco, 2003; Torvinen, Kannus, Sievanen, et al., 2002) and kettlebells training exercise (Otto, Coburn, Brown, et al., 2012; Lake & Lauder, 2012; Manocchia, Spierer, Lufkin, et al., 2013) will probably improve athletes lower body proximities of power and strength characteristic. Even though all this training methods exist to further improved and developed the lower body power of an athletes, earlier research has shown that weight lifting movement such as snatch can administer a superior training stimulus (Otto, Coburn, Brown, et al., 2012; Tricoli, Lamas, Carnevale, et al., 2005; Hoffman, Cooper, Wendell, et al., 2004; Khamoui, Brown, Nguyen, et al., 2011; Chiu & Schilling, 2005). Due to this, weightlifting movement such as clean and jerk, snatch are and their derivatives such as power clean and power snatch are frequently used as a method to train the lower body muscular power which involves the triple extension movement (Hori, Newton, Nosaka, et al., 2005; Newton & Kraemer, 1994; Comfort, Allen, Graham-Smith, 2011; Comfort et al., 2011; Cormie, McCaulley, Triplett, et al., 2007; Hedrick, 2004; Hydock, 2001; Kawamori & Haff, 2004; Takano, 1992). Weight lifting exercise such as snatch are very popular among strength training program for power based sports athlete because of the

similarities between the triple extension moment of the lifting movement and those seen in majority of power based sports and athletics movement (Hori, Newton, Nosaka, et al., 2005). To be more specific, previous studies has indicated that there is a strong relationship exist between the weightlifting movement such as snatch and sprinting (Hori, Newton, Andrews, et al., 2008; Stone, Byrd, Tew, et al., 1980), vertical jump (Hori, Newton, Andrews, et al., 2008; Canavan, Garrett, Armstrong, 1996; Carlock, Smith, Hartman, et al., 2004), and change of direction (Hori, Newton, Andrews, et al., 2008).

Snatch lifting emphasize on the power output and the usage of proper triple extension joint in order to successfully lift a heavy load. The snatch which is also the main topic for this thesis and a lot of its variation are a very useful training exercise for this kind of athlete. Among the variation of snatch are classical snatch (uses in weightlifting competition), power snatch, snatch from hang, split snatch, snatch from different height of blocks, snatch from kneeling position and also one-legged snatch. It is crucial to understand the biomechanics of snatch. Biomechanical and technical knowledge of both competition and training exercise will give the coaches a good understanding to guide the athletes towards greater training efficiency and to avoid any future injuries.

Technically as an overall movement, the snatch can be categorise into 5 different position that is the first pull, transition phase, second pull, turnover, and recovery. The analysis of biomechanics has proven that there is an important and direct relationship between force exerted and the velocity of snatch lift during this phases (Ho, Lorenzen, Wilson, Saunders, & Williams, 2014; Ho, Williams, Wilson, & Meehan, 2011). Literally, all the work done during snatch lift occurs at the phase where the centre

of mass of the barbell achieve at height slightly above waist height of the lifter (Garhammer, 1993). There is a point where the maximum velocity occurs during Olympic movement which is when the position of the body is fully extended, (ankle, knee, and hip). Inversely during this time, the concentric muscle force would be near minimal force. Therefore, it can be said that the maximum power output happen at the time when the barbell is in the interchange phase between the first pull phase and the second pull phase before the lifters caught the barbell over their head. That is the moment where maximum power output is produce. The snatch pull exercise is considered to be ballistic in nature because it involved the concentric movement of the lower body muscles (Garhammer, 1993).

Unfortunately, in countries where the application of weight training is scarce or non-existence due to the lack of equipment or lack of the knowledge of sports science, snatch is often time associated to or only done by those in weightlifting sports only. In fact, snatch is rarely done sometimes by athlete from different sports because it is normally mistaken as an activity only done by the weightlifters. Snatch is actually an exercise which is used in various power based sports and it is normal in countries which has a high knowledge of sports science application and also high sports ranking. This is because snatch is proven to be beneficial in terms of power production (Hori, Newton, Nosaka, et al., 2005; Newton & Kraemer, 1994; Comfort, Allen, Graham-Smith, 2011; Comfort et al., 2011; Cormie, McCaulley, Triplett, et al., 2007; Hedrick, 2004; Hydock, 2001; Kawamori & Haff, 2004; Takano, 1992). The heavier the load an athletes can lift during snatch with a correct posture, the greater the power performance can be seen during the execution of their sports skill.

Kinematic and kinetic is two of the most important variables in snatch lifting. A successful lift will majorly be dependent mostly on the manipulation of the kinematic and kinetic variables on the human body. Both kinetic and joint kinematic data were recorded because they provide the most detailed and sufficient information about human movement. To explain kinematic and kinetic in terms of biomechanics, human anatomy is taken into context.

Kinematic is considered as the examination and description of the forces causing motion (Hamill & Knutzen, 2006).Kinematic can be explain simply as the way the body moves. Kinematic analysis of movement takes into account the measurement of velocity, position and acceleration of one or several body parts. Linear measurements of specific parts, angular measurements at joints, or a combination of all that can be performed in order to calculate and determine the temporal properties of movements of multiple body parts simultaneously. It is normally advice for kinematic measurements to be made in three dimensions to gain more data compared with two dimensional. This type of analysis may be conducted on fundamental movements or sport-specific tasks to identify right–left differences and identify injury risks (Gundersen et al., 1989; Pappas & Carpes, 2012; Zifchock, Davis, Higginson, McCaw, & Royer, 2008).

Kinematic explains how the human body parts moves. The human anatomy is really complicated thus it is really difficult to describe how all of our body part moves. An example to making it easier to describe is by making a model of the bodies. This model has multiple segments that can be referred to segments major bone for example the pelvis, femur, tibia, trunk and head. Each of this segment is considered rigid or static which means it does not move or change when the body is moving. Each segment have a coordinate system as a way to easily and systematically detect and analyse the

movement through a 3D camera system. To describe the relative location of two coordinate systems in three dimensions, three numbers are required and these are referred to as joint angles. Generally, for many purposes within gait analysis it is simple to consider these as sagittal (generally flexion and extension), coronal (generally abduction and adduction) and transverse plane (internal and external rotation) joint angles. All this motion is a way of describing the movement that occur during a certain sports movement such as during the execution of snatch accurately (Pappas & Carpes, 2012; Zifchock, Davis, Higginson, McCaw, & Royer, 2008). It will make it easier to determine the motion of movement by categorising them in such order of group. Each of this joint angles can be calculated using software system such as vicon or qualysis.

Kinetic on the other hand is describe as the forces and moment acting on the human body. Kinetic is defined as the examination and description of the forces causing motion (Hamill & Knutzen, 2006). The forces and moment are the variables that cause the body to move in the way that follows the law of physics which is the same for any other mechanical system. Forces act with the reason to accelerate a body and it is independent to where the forces are applied. A force can be fully describe if the magnitude and the direction on which it is acting is known. The most important force in gait analysis would be the ground reaction force which can also be describe as the force exerted by the ground on the foot. It is called reaction because of the reason of the newton third law which says that for every action, there is an equal and opposite reaction.

Power, speed, muscular strength, nutrition and sport skills are all factors of success in competitive athletics (Pearson, 2000). Even though power and strength are highly related to sporting success, the ability to execute force in a correct sequence and

motion is also crucial and important. It is currently believed that the capability to demonstrate appropriate and optimum technique is dependent on the level of fatigue. Due to this factor, the capability to maintain and retain good exercise technique form over a multiple repetitions would be of interest towards coaches and athletes. Fatigue will always occur to human body as it is how the human body physiology works. The best we could do is to slow down the effect of fatigue towards performance output in any sports as fatigue does not only impaired performance, but also the technique (Halil et al., 2009).

It is generally and widely known that fatigue could deteriorate an athlete's performance and moreover brings a significant changes towards their technique. Fatigue induces adverse effects of exercise performance through manipulation to technique and motor control and there are a lot of research that could proof it. In a research by Halil et al. (2009), he found that postural stability to be jeopardized following fatiguing exercise in volleyball players. Another study by Gabbett, (2008) shows that there is a reduction in tackling techniques if the athletes is under fatigue. Furthermore, athletes which shows the best tackling technique during a non-fatigue condition shows the most decrement in technique under fatigue condition. Stone and Oliver (2009) in their research previously also found that fatigue in soccer players would decrease their kicking performance during training. Studies also suggest that incompetent inter-muscular coordination and depression of muscular force plays a vital role in kicking performance decrement (Apriantono, Nunome, Ikegami, & Sano, 2006). To add on to the effect of fatigue towards athletes, Apriantono et al. (2006) also come to a conclusion in their studies that when there is a fatigue condition in soccer players, their leg swing speed would decrease and the player's ball contact would become poorer. All this studies strengthen that fatigue would bring negative effect towards

performance of sports either during competition or during training. If we are able to overcome or possibly decrease the negative effect of fatigue condition in training, it would surely be of benefit towards the athlete's population. Coach could have planned a better and improved training regime that would take into account the fatigue effect and ways to overcome the negative effect of fatigue. This should be done not only towards the performance output, but also with their technique in a biomechanical level such as their joint kinetic and kinematics as to strengthen the supports towards the claims of techniques used to decrease the negative effect of fatigue.

Normally, training for a power based sports would include high load intensities training. The principal of neurological overload is applied here in weight training because normally the athletes should lift high load intensities ranging from 80-120% of their 1RM. Reason here is because when we are training at load higher than 1RM, it will allowed for neurological adaptation to take place and this is in line with the specific adaptation to induced demand principle (SAID) (Cormie, McGuigan, & Newton, 2011; Suchomel, Comfort, & Stone, 2015; Suchomel, Wright, Kernozek, & Kline, 2014). Unfortunately, there would be one negative feedback that would occur when the athletes are training with high intensity load together with high repetition that is fatigue. Normally, in traditional training method, neither athletes nor coach would look seriously into this fatigue effect as it is not significant for the naked eyes, but truth to be told, it did takes a toll on performance as well as the kinetic and kinematic of the athletes. To the coach, 'no pain no gain' and 'the more you do the better you get' thinking and ideology is always being applied in their training regime. The old timer coach generally depends on their experience in coaching their athletes and the scientific behind the sports are often neglected thus creating the norm of the harder you trained

non-stop, the better you are going to be. This area already proven to be wrong as the effect of fatigue are often significant.

To backed the claim that fatigue would be detrimental towards performance, kinetic and kinematic of athletes, (Hardee et al., 2012; Hardee et al., 2013; Oliver et al., 2016; Valverde-Esteve et al., 2013) has shown that with increasing intensities or loads during weightlifting training by either using a barbell or dumbbell exercise, this could lead to increase in fatigue level and would negatively affect the technique, rate of perceive effort and power output. Furthermore, with the combination of increasing intensity of lifts, consecutive non-stop repetitions and sets would have also shown to negatively affect athlete's performance. (Hardee et al., 2012; Hardee et al., 2013; Oliver et al., 2016; Valverde-Esteve et al., 2013). This few previous research shows the negative effect of what fatigue could do towards the performance.

Apart from performance, a closer related matter that would definitely be impacted by this fatigue condition would be the kinematic and kinetic of joints in athletes especially during their training exercise. Generally most coach only see the technique by using their naked eyes and determine whether they are doing it right or wrong. However, by using a three dimensional camera, a lot more data are able to be detected to confirm if their technique changes across time or become slower due to fatigue or even become terribly wrong and could induce injury. Biomechanics of lifters is very important to maintain during practise as this will lead to an autonomous movement when they are going for competitive competition. It is very crucial to get the training mechanical movement part corrected by expert coach before they go for the real competition. This is because when they are doing a higher load and longer repetition exercise, their joint kinematic or in an easy word their joint movement may

either jeopardize or become varies across time especially towards the joint kinematic and also kinetic which could become slower or varies significantly with the first repetition. All of this comes from the effect of fatigue (Hardee et al., 2012; Hardee et al., 2013; Oliver et al., 2016; Valverde-Esteve et al., 2013). Success and failure of full weightlifting movement comes from the combination of kinetic and kinematic factors of the barbell and body variables. There are a lot of research looking into the sports of snatch and their performance output variables and how it could affect the outcome of snatch. However, very less research has been focusing on the joint kinematic and kinetic during snatch or any other weightlifting method of training. Fortunately, there are few research that has been done to shows the detrimental effect of fatigue towards the kinetic and kinematic variables of performance measured in athletes.

Kinetic variables is basically referring towards the force and power output production of the whole body during the process of snatch or the joints kinetic of lower extremities and upper extremities. It can also be the joints involve like the ankle, knee and hip joint and the force production during lifting of the barbell. So it is definitely crucial to obtain an optimum and high force output production during the execution of snatch as this will ensure the success rate of the snatch movement. It is also beneficial if an athlete are able to produce higher power output while executing a snatch lift. However, due to the detrimental effect of fatigue, kinetic variable such as force and power production during snatch could be significantly lower across repetition. It will be more severe if the repetition is without a rest period. Lower force output will means that the velocity is slower. With slower velocity, the power output will be lower and this could eventually resulted in a fail snatch lift.

Muscular power is highly important in a wide variety of sports including weight lifting, strength training and athletics in general (Cormie et al., 2011; Hardee et al., 2012; Oliver et al., 2016). Work done by athletes in a burst or in a very short and explosive time can be categorise by both kinetic and potential energy of the total system being worked out. Power output, or given the formula as work done divided by time taken, has been used as performance measure since way back (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002). Power output can be also mention as the relationship between maximal force and velocity where 'Power = Force x Velocity' (Cormie et al., 2011). Since the ability to deliver maximum force and power output during a competition of a sport is crucially beneficial, training method to increase and maintain the power output and force output is of the greatest interest for researcher and it has given rise to a few new research design and literature. Furthermore, past literature has been supporting that the ability to generate maximal power and force help improved athletic performance (Ho et al., 2014). Literally, the ability to optimize power and force output while engaging in training stimulus should maximize one's ability in athletics bouts (Cormie et al., 2011). All of this variables of training will eventually help in getting a successful snatch lift with the bar in an overhead position.

When fatigue set in as a result of non-stop repetition training, basically, a lot of negative effect will occur along and this will be detrimental towards the kinetic variables mention above (Hardee et al., 2012; Hardee et al., 2013; Oliver et al., 2016; Valverde-Esteve et al., 2013). When the athlete is fatigue, in general, less force will be produce and when less force is being produce, the speed of the barbell will become slower because the power output is smaller. This in the end will create a chain reaction of failed snatch lift which required the athletes to use a lot of energy. Hardee et al. (2013) shows in his research that power output is significantly reduce when multiple

repetition and intensity increases. Reduction in power output is measured by the decreasing in force and velocity exerted during the snatch lift (Hardee et al., 2012; Hardee et al., 2013).

Same goes for kinematic variables. Kinematic variables in snatch movement also will be affected by fatigue. Technique would become poor by time and repetition and so do the joint kinematic. Joint plays a very important part in producing the right movement and also the optimum for by working simultaneously. To be more specific, joint movement of ankle, knee and hip joint plays a very significant and crucial role in snatch process. If one of this joint failed to function properly, it could poorly reflected in the successfulness of the snatch lift. The lift could fail not be done successfully and injury may occur due to fatigue which in turn jeopardise the movement of the joint. Apart from joint movement, the trajectory of the barbell pathway and the barbell velocity also plays an important role in determining a successful lifts. All this biomechanical factor and many others which include kinetic and kinematic during the execution of the snatch lift is of utmost important because it is the determining factor whether an athletes are able to lift heavier, successfully and with the correct technique being executed to avoid any injury.

With the knowledge of the detrimental and negative effects of fatigue on exercise technique, power output, kinetic and kinematic of lifting be it towards the barbell, or the joint movement, the barbell pathway and also the performance, it is very clear that it is of utmost importance that a methods to minimize fatigue should be of interest during training for the coaches and this could benefit majorly for the development of exercise technique during snatch. Muscular power and exercise technique are also impaired during fatigue period therefore training methods that would

minimize fatigue would be greatly beneficial towards the development of the athletes who use the snatch lift as a training method to improve speed, force and power. Fatigue is not a fairy tale that could be ignored because its consequences is quite severe during training. With all the effort by coaches and sport scientist to try and maintained the barbell kinematic values such as velocity and displacement during explosive movement is a sure indicator of fatigue reduction effect (Hardee et al., 2012; Hardee et al., 2013). Neuromuscular fatigue that occurred across a variety of training exercise that reduces the muscular power output also strengthen the fact that fatigue is not a good thing (Hardee et al., 2012; Hardee et al., 2013; Oliver et al., 2016; Haff et al 2003). Ultimately, the performance output such as barbell measurement of velocity, power and force has been shown to decrease with increasing fatigue (Hardee et al., 2012; Hardee et al., 2013; Oliver et al., 2016; Haff et al 2003). Therefore, a way to overcome fatigue in order to reduce the decrease of all the performance output would improve the barbell mechanics and ultimately will optimize the performance stimuli which could finally induce maximal adaptation towards the athletes (Hardee et al., 2012; Hardee et al., 2013; Oliver et al., 2016; Haff et al 2003).

Not long ago, Inter-Repetition Rest has become a method of interest for the attenuation of fatigue during resistance and weight training. Inter repetition rest is a rest period given between repetition different as normally done between set to overcome the effect of fatigue. The selection of appropriate rest interval is important in order to maintain a high velocity, force production and power throughout the repetition and set. Continuous repetition and set are structured to produce a high level of fatigue thus will be detrimental towards power development because of slower velocity and lower production of force by the end of the set. Inter repetition rest is introduce to prevent a high level of fatigue. Inter repetition rest intervals allows for phosphocreatine (PCr)

stores to replenish and may result in faster velocity and higher rate of force production. How to determine the correct duration for inter repetition rest depends on how fast the energy molecule of ATP and PCr can be resynthesized. This need to be taken into account while considering how short a rest duration can be given between repetitions to avoid the similarities of rest between sets. According to Fleck and Kraemer (1987), 90 percent of the ATP and PCr stores can be resynthesized in 1 minute by oxidative metabolism. Harris et al. (1976) and Forbes et al. (2009), suggested that the time for PCr to resynthesize could be as fast as 21-22 seconds in the fast phase of recovery. Taken into consideration, a rest duration of under 1 minute could be a great indicator to use as a rest duration for between repetition.

Inter- repetition rest method has been shown to maintain the kinetic and kinematic variables across multiple repetition over a time period (Haff et al., 2003; Hardee et al., 2012; Hardee et al., 2013; Oliver et al., 2016). It also could maintain the power output and optimal barbell kinematic during weight training in multiple set and repetition routine without fatigue taking its toll too deeply. This is ground breaking as it is a way for coaches to overcome the negative effects that fatigue introduce. To date, several studies has been done by the strength and condition experts to test the validity of the said inter repetition rest method and so far it has yield good result. This method of training is done by giving a rest of (10-40 seconds) between repetitions of high intensity training. Haff et al. (2003) in his research showed that by applying Inter-Repetition Rest in his cluster set configuration training method, the barbell velocity is significantly higher compared to traditional method at 90% and 120% of 1 repetition maximum (RM) during the execution of clean pull. The barbell displacement also increase significantly compared to the traditional method at 120% intensity (Haff et al., 2003). Greater power output is also shown in bench press exercise per repetition with

the application of Inter-Repetition Rest when compared with traditional continuous repetition exercise method (Lawton, Cronin, & Lindsell, 2006). Furthermore, total power output for the bench press is also significantly increased by 21-25% when compared with the traditional method of continuous set exercise. (Lawton et al., 2006). These research has given us the insights of what IRR are capable of and the benefit of practising it.

Inter-repetition rest is a rest period ranging from 10-40s that was given to athletes between their continuous repetitions (Haff et al., 2003; Hardee et al., 2012; Hardee et al., 2013; Oliver et al., 2016). The reason why this inter repetition rest configuration is giving a benefit to athletes in term of power output and also kinetic and kinematic variables significantly if compared to traditional methods which has no rest period between consecutive repetition is because of the physiology of the human body. Rest is important when we are working out and exhaustion only bring us negative outcome rather than positive when we force ourselves to workout in that condition without realizing our body condition. When we implement short rest, our phosphocreatine (PCr) is stored again partially in a process called re-phosphorylation (Haff et al., 2003; Oliver et al., 2016). Creatine is the substance that are responsible to generate the burst of energy that we need when we workout and when this is depleted, it will cause us to have low energy storage. When we have less energy to use, the power output will become less and the ability to stabilize our body during workout also will diminished as all this required work and work is energy. When we have less energy, fatigue will set in and cause a lot of negative impact to our kinetic and kinematic variables during weight liftings especially the snatch workout because snatch is an overall body exercise and it required a vast amount of energy to complete such a high intensity workout.

Physiologically, the positive benefit of implementing this short time of rest inter repetition is to give an ample time for the re-phosphorylation of phosphocreatine (PCr) to happen (Oliver et al., 2016; Haff et al., 2003). Creatine phosphate (PCr) is a type of phosphorylated creatine molecule that function as a rapidly mobilized reserved of high energy phosphate that caters for high energy demand in skeletal muscles, myocardium and the brain to recycle adenosine triphosphate (ATP) (Hardee et al., 2012; Hardee et al., 2013; Oliver et al., 2016; Haff et al 2003). Why this process is important and what it has to do with fatigue? Muscle cells use this phosphorylated form of creatine to store energy. Normal metabolism cannot produce energy as quickly as a muscle cell can use it, so an extra storage source is needed. The phosphate group can be quickly transferred to ADP to regenerate the ATP necessary for muscle contraction. However, it still need time to be done. With a continuous training method, this phosphate molecule would have no time to resynthesize and be depleted which is the reason of all the performance decrement. Short rest period could the favor by allowing the molecule to be synthesize and the performance output of kinetic and kinematic during snatch could be maintained to produce the best result in snatch.

Research on inter-repetition rest (IRR) has been done a lot in the strength and conditioning field and it has shown to benefit power and strength workout a lot (Haff et al., 2003; Oliver et al., 2016). They also found that when implementing the IRR protocols, the power output, technique, and rate of perceived effort were all conserve when compared to traditional set of continuous repetition in power clean exercise (Hardee et al., 2012; Hardee et al., 2013). IRR also shows the same promising outcome in strength exercise such as the bench press and the squat exercise (Oliver et al., 2016; Valverde-Esteve et al., 2013). Valverde et al. (2013) found that by implementing an inter-repetition rest of 15s in duration, the power output is maintain significantly if

compared to 0, 5 and 10 seconds of IRR treatments. Oliver et al. (2016) also showed a significant conservation of power output and barbell velocity when using IRR protocols compared to traditional method in barbell squat exercise. Accordingly, this shows that IRR has been shown to be important in preventing the negative effect of fatigue and is beneficial for performance in barbell weight training exercise.

1.2 Problem Statement

Until now, there have been a lot of researches been conducted on snatch (Ho, Lorenzen, Wilson, Saunders, & Williams, 2014; Akkus, H., 2012; Ho, Williams, Wilson, & Meehan, 2011; Chen, YH & Chiu, HT., 2011; Chiu, HT, Wang, CH, and Cheng, KB., 2010). However, in terms of biomechanically, little to non-research has been done to proof this in joint movement level. To see that if the claim by the strength conditioning experts is also true in the view of biomechanical movement. There is a lot of research looking at the kinetic outcome of the barbell and also the force exerted but little to none research is done to see closely at the joint level of velocity and angle displacement. What is the difference that occurred in joint level and by phases of snatch because each of the specific phases in snatch plays an important role towards the next phases in order for successfully completing the snatch movement. If a study which focuses more towards the joint kinetic and kinematic in each phases is conducted, and the result clearly supported what the field of strength and conditioning is claiming, than this is a great result in biomechanical field. This could be an important findings to be used by coaches and also teachers in implementing a training method to athletes. Furthermore, the snatch movement is not only used by weightlifting athletes, it is also implemented by the power based sport athletes to build their power production in their specific sports.

There are plenty of previous researcher who focuses the snatch research towards only weightlifting athletes but the truth is, snatch is widely implemented by all types of athletes especially towards power based sports athletes. This research thesis could especially look deeper towards the power based sports athletes and how the implementation of IRR benefits them in training using snatch movement and also implanting a consciousness in the society mind that snatch is not only for body builder or weightlifting athletes.

The effects of inter-repetition rest on the kinematic and kinetic of ankle, knee and hip joint in snatch exercise is generally unknown. Even though previous exercise literature on the effect of inter-repetition exist, non to this date focuses on the kinematic and kinetic of snatch specifically towards the joint kinematic and kinetic after the implementation of IRR. IRR sole focus has been to negate the negative outcome of fatigue and a few literature has been develop to back that statement (Hardee et al., 2012; Lawton et al., 2006; Valverde-Esteve et al., 2013).

Despite all that studies, the importance of the joint mechanics while executing the lift after implementing IRR has been looked aside. The final outcome may increase or maintained the performance and power output by implementing the IRR protocol based on previous literature but less has looked closely into the kinetic and kinematics of the joints after implementing IRR. It is very important to look into this because with a wrong or unstable joint movement while executing power exercise, it may lead the athlete towards a future full of injury. Power lifting sports is all about technique and a small mistake while executing it will surely backfire the athletes (Ho et al., 2014; Pearson, 2000). Coach on the other hand is all about the performance. Athletes is often labelled as a short period performer because an athlete is neglected once he or she is

not able to perform because of injury or is stagnant for a long time in terms of performance increment. This small knowledge of looking into the kinetic and kinematic of the joint will play an important role in determining whether an athlete is doing it right all-rounder or just executing it with nothing but brute force.

Few studies regarding IRR have been done on the biomechanics of weight lifting and although they did mention kinetic and kinematic performance as their variables, yet the final output is always to see the performance related variables that is the peak power output, the velocity of the barbell, the barbell pathway and the barbell displacement (Haff et al., 2003; Lawton et al., 2006). None so far focused on looking at the effect IRR has on the kinetic and kinematic of the joint especially the ankle, knee and hip joint which is responsible for the execution of all power lifting from the ground. The triple extension joint. Lack of research has been conducted on analysing how the joints kinetic and kinematic acting after implementation if IRR. It is unclear whether the various IRR duration implemented during the snatch lift will provide possible benefit to the movement enhancement and the acute responses that will then affect performance.

In strength and conditioning field, there are a lot of literatures about the kinetic and kinematics of snatch. The benefits of strength and power through the optimisation of resistance and weight training has been the source of argument amongst strength and conditioning experts, health experts and also researcher for years. As we know, weight training will involve a high number of repetition, sets and load to activate and contract the muscles. Continuous training such as the traditional training method will obviously result in failure to sustain the intensity of training as fatigue sets in during multiple set or repetition training regime. Therefore, the need of rest in order to overcome this

problem within training session become crucial in order to maintain the training intensity. Normal practise of giving relatively 60-90 seconds of rest is targeted for maximal strength adaptation that is to increase the size of the muscles. Rest between 180-300 seconds is normally used for strength adaptation workout which involved the enhancement of neural function and increase maximal power adaptation (Baechle, & Earle, 2008). All this rest duration is normally given between sets.

However, to date, there is no optimum time duration of rest given for inter-repetition rest duration. Inter-repetition rest has been theorised to provide time to allow the partial resynthesize of the intramuscular phosphocreatine stores, which will ultimately allowed the athletes to increase their training volume and high intensities for a longer duration or performing additional repetition (Berg, 2003). Furthermore, there is also less literature about the performance output on weightlifting when applying this method of rest towards training. Research about inter repetition rest is still in its infancy and there are many theories surrounding inter-repetition rest training that are currently unsubstantiated.

Additionally, there is little data that a two-dimensional analysis could provide with snatch data collection compared to a three-dimensional kinematic analysis which are more dependable. Usually a two dimensional data analysis used only one camera which generally will faced with certain problem that is an obstructed view of the knee behind the weight themselves over a wide range of movement which could result in less precision in measurement. Secondly, the angles data taken from a single plane may be overestimate and distort the true values (Baumann, Gross, Quade, Galbierz, & Schwirtz, 1988).

In short, to summarise it in point,

a) Less study has been focusing on the effect of Inter-repetition rest towards joint kinematic of ankle, knee and hips. They focused more on performance output (Hardee et al., 2012; Lawton et al., 2006; Valverde-Esteve et al., 2013).

b) Technique in terms of kinematic and kinetic of joint after implementing Inter-repetition rest is the same important as the performance output. To confirmed if the effect of inter repetition rest is the same with joint kinematic as it is with the performance (Haff et al., 2003).

c) Unstable joint and body movement during executing the snatch is dangerous and may lead to injury. Inter-repetition rest should negate this as minimum as possible (Ho et al., 2014; Pearson, 2000).

d) It is unclear and less study has been done to see what various Inter-repetition rest duration implemented will benefit the athletes in terms of movement and also performance.

e) How athletes produce power is more important than the power they produce (Matt Kritz, 2012).

Therefore, this research will not only strengthen the understanding of inter- repetition rest effect towards athletes in terms of kinetic and kinematics of joint, it will also add on to the performance output literature out there using the three-dimensional kinematic analysis of the snatch technique.

1.3 Objective of Study

The studies in this thesis addressed the following objectives:

1.3.1 To determine the maximal angle of ankle, knee and hip joint during different inter-repetition rest duration of snatch by phases.

1.3.2 To determine the maximal joint (velocity) of ankle, knee and hip joint during different inter-repetition rest duration of snatch by phases.

1.3.3 To determine the mean peak barbell velocity during different inter-repetition rest duration of snatch.

1.3.4 To determine the mean peak vertical ground reaction force (GRF) during different inter-repetition rest duration of snatch.

1.3.5 To compare the maximal angle of ankle, knee and hip joint during different phases with different inter-repetition rest duration of snatch

1.3.6 To compare the maximal joint velocity of ankle, knee and hip during different phases with different inter-repetition rest duration of snatch.

1.3.7 To compare the mean peak barbell velocity among different inter-repetition rest duration of snatch.

1.3.8 To compare the mean peak vertical ground reaction force (GRF) among different inter-repetition rest duration of snatch by phases.

1.3.9 To compare the peak values of Ankle, Knee and hip joint angular velocity, maximum ground reaction force, and maximum barbell velocity between 1st and 5th repetition during each IRR protocol.

1.4 Hypotheses

The studies in this thesis addressed the following hypotheses:

1.4.1 There are no significant differences between the maximal angle of ankle, knee and hip joint during different phases with different inter-repetition rest duration of snatch.

1.4.2 There are no significant differences between the maximal joint velocity of ankle, knee and hip during different phases with different inter-repetition rest duration of snatch.

1.4.3 There are no significant differences between mean peak velocity and Inter-repetition rest duration of snatch.

1.4.4 There are no significant differences between mean peak vertical ground reaction force (GRF) and Inter-repetition rest duration of snatch by phases.

1.4.5 There are no significant differences on the peak values of Ankle, Knee and hip joint angular velocity, Maximum ground reaction force, and maximum barbell velocity between 1st and 5th repetition during each IRR protocol.

1.5 Significance of Study

Athletes involved in sports such as sprinting, jumping, rugby and weightlifting subject their bodies to a lot of lower bodies' movement during training and game. Lower body power development is one of the most crucial factor in athletics performance that required the usage of the triple extension at the hip, knee and ankle joints. Triple extension joint is oftentimes used in a range of sports that used explosive movement

such as jumping, sprinting and change of direction (Cormie, McGuigan, & Newton, 2010). The snatch on the other hand, involves four continuous phases of the movement up to triple extension of the ankle, knee and hip joint and lastly the scapular elevation when in shrug motion (Comfort, Allen, & Graham-Smith, 2011). Triple extension joints play and important roles during the execution of snatch and also all power based sports.

However, training stimulus which includes high force and power production are necessary for neurological adaptation and sport performance (Cormie et al., 2010). Thus, continuous repetition, increasing numbers of sets and high load is a must. This in the end will trigger fatigue which will be detrimental towards performance and specifically towards traditional strength and power exercises. Inter-repetition rest (IRR) has been applied as a way to overcome this setback by fatigue, yet little is known about the effect of IRR towards the triple extension joints behaviour after undergoing training with implementation of IRR with different rest duration. The behaviour of kinetic and kinematic of the triple extension joints will majorly affect the outcomes of performance and also their basic movement. Performance may maintained across repetition compared to traditional method but the way it is done is important in order to avoid injury in the future. By understanding the kinetic and kinematic behaviour of the triple extension joints during different duration of IRR implementation that affects the mechanics of movement will provide valuable insight into the stimulus imposed on the physiological system during training. The different effect will provide information on the training specific responses, such as differences in performance variables. Findings of this study will demonstrate how different duration of IRR given will affect the kinetic and kinematic of the triple extension joints in terms of the biomechanics responses.

This study will also provide knowledge in the effectiveness of inter-repetition rest with different duration towards the performance variables of snatch lift. Power

output, velocity production and force during movement are physiological markers for human performance in sport. To overcome the regression of power output, velocity and force in barbell exercise, IRR protocols have been implemented by experts from strength and conditioning field. IRR treatments have been shown to likely assist with acute performance variable regression but the research is still on its infancy and little literature are done to back this up. To date, no optimum time duration are given as the best time duration to be applied for inter-repetition rest duration. This study will provide and strengthen the literature on advantageous of inter-repetition rest with different time duration towards the performance output of snatch lift. This is beneficial as it will provide better understanding on the importance of applying IRR for performance output maintenance during training.

Furthermore, this research includes the usage of latest technology in sports science that is the Vicon camera (3D camera) and force plate used together with the software of Polygon and Matlab which is considered as the gold standard measurement machine in the of biomechanics. This will bring a significant research on the effect of IRR towards the joint biomechanics and performance output during snatch training in sports science field in Malaysia.

Overall, findings of the present study will contribute to a richer understanding on the practise of IRR particularly on weight training exercise specifically the snatch lifting. It is also expected to enrich the existing body of knowledge and understanding from perspective of kinetic and kinematic of triple extension joints which is very useful for sports coaches, conditioning coaches, fitness coaches, athletes, exercise rehabilitation therapist and strength training enthusiast.

1.6 Delimitations

The studies in this thesis were conducted with assuming the following delimitation.

1.6.1 All participant were delimited to male's athletes that are currently active.

1.6.2 All participant had at least 3 years of weight training experience.

1.6.3 All participant had a snatch 1 RM of at least bodyweight.

1.6.4 The participant in this study were delimited to recreationally active, resistance trained men.

1.6.5 All participant were delimited to those who meet the inclusion criteria, which required the participant to be free of any physical, musculoskeletal or neuromuscular limitation, disease or inhibition that would prevent the participant from performing the test. They must be healthy and injury free.

1.6.6 All testing is done at the same time of day.

1.6.7 All subjects were currently training on a weightlifting program.

1.6.8 All the assessment and training session were conducted at the Faculty of Sports Science and Coaching Biomechanics Lab, UPSI.

1.7 Limitations

For this study, the limitation that had arisen were:

1.7.1 The participant dietary intake is not controlled.

1.7.2 The variability in day to day training difference.

1.7.3 Not all factors that affect the performance are controlled for example psychological and physiological factor.

1.8 Assumptions

For this study, it is assumed that:

1.8.1 All the subjects performed maximally

1.8.2 All the participant adhered to the given training, rest and recovery protocols.

1.8.3 All the participant performed the best to their abilities.

1.9 Definition of Terms

1.9.1 Continuous training

The performance of resistance exercise in a steady manner (e.g. each repetition immediately follows the previous one until muscular fatigue or the end of the given number of repetitions). Rest are given between sets of continuous training. Continuous training in this research refer to a continuous exercise motion done without rest in between repetition.

1.9.2 Inter-repetition rest

The prescription of rest intervals between individual repetition (Lawton, Cronin and Lindsel, 2006). Inter-repetition rest periods are most commonly associated with the assessment of strength and power. Rest between each repetition. Inter-repetition rest in this study refers to the duration of rest given to the athletes in between of snatch repetition done.

1.9.3 Inter-set rest

The prescription of rest intervals between sets if exercise. Inter-set rest intervals are typically associated with continuous training schemes. Inter-set rest in this study refers to the duration of rest given to the athletes in between set of snatch done.

1.9.4 Kinematic

The examination and description of the forces causing motion (Hamill & Knutzen, 2006). Kinematic in this study refers to the joints displacement, joints velocity and barbell velocity.

1.9.5 Kinetic

The examination and description of the forces causing motion (Hamill & Knutzen, 2006). Kinetic in this study refers to the maximum vertical ground reaction force (GRF).

1.9.6 Repetition Maximum (RM)

The highest number of times that a particular mass can be successfully lifted (Knuttgen, 2003). For example, a 6RM load is the greatest load that can be successfully lifted six but not seven times. Thus 1 RM is the maximum amount of force that can be generated in one maximum contraction. Repetition Maximum in this study refers to the maximum amount of weight an athlete in this study can snatch successfully.

1.9.7 Velocity

Rate of change of position, commonly referred to as "speed with a direction". Velocity in this study refers to the velocity of the ankle, knee and hip joint and also the velocity of the barbell during the execution of snatch.

1.9.8 Fatigue

Reversible decline in muscle performance associated with muscle activity that is marked by a progressive reduction in force generated by muscle (Allen, Lamb & Westerblad, 2008). Fatigue in this study refers to the decrease in performance by the athletes during snatch. Tiredness.

1.9.9 Force

Mass multiplied by acceleration of movement. The ability to generate contraction against a load by action of muscles. Force in this study refer to the amount of force exerted by the participant during the execution of snatch towards the force plate.

1.9.10 Traditional Sets

Continuous repetition with no rest. Traditional sets in this study refers to the normal no rest in between of repetition exercise.

1.9.11 Triple Extension

Triple extension refers to the movement that happens when the ankle is dorsiflexed, the knee and hip are flexed in a stationary position and then rapidly the ankle is plantar flexed and the knee and hip are extended. (Waller et al., 2007).