NORWEGIAN SCHOOL
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Emma M.E.K Hald

Can Priming Sessions Enhance Performance in Olympic Weightlifters?

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Abstract

Introduction: There are many factors influencing performance in Olympic weightlifting (weightlifting) competitions. In most sports the margins between winning and losing are small and the outcome of the competition is therefore more complex than just the amount of training and recovery over a longer period of time. There have been suggested a window of a delayed potentiation after a previous resistance training session (priming session). It could therefore be hypothesized that a priming session the day before and on the day of a competition could enhance performance. Earlier studies have reported that a potentiation may last for as much as 72 hours after a priming session. This potentiation is induced by the contractile history of the muscles, but this contractile history can also induce fatigue. Finding the optimal training routine, the day before a competition could possibly enhance the performance in athletes. The purpose of this study was therefore to investigate if different priming sessions could affect the subsequent performance in weightlifting and other power movements in the lower limbs.

Method: Seven male (n=3) and female (n=4) weightlifters were exposed to three different conditions: low/moderate resistance priming session (LR), high resistance priming session (HR) and rest day (CON). Performance in maximal velocity in weightlifting, force-velocity relationship in pneumatic leg press and vertical jump height (generic tests) were measured 24 hours after each condition.

Results: There was a significant difference between HR and LR for SJH (p= 0.01). And a significant difference between HR and CON in force from the pneumatic leg press (p=0.03). There were no significant differences in weightlifting performance between these three conditions.

Conclusion: There is findings showing a significant difference between LR and HR in SJ height, and CON and HR in force in pneumatic leg press. Based on performance index, there is also a trend towards LR being the more favorable priming session for jumping height and force velocity relationship. No significant differences were found in weightlifting performance after the previous conditions.

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Preface

Due to the outbreak of Covid-19, testing for this project was not finished. This project was mainly affected by the lockdown of the school and therefore also the laboratory and gym. This caused an early termination of the testing period. Two participants were therefore not able to finish testing.

A big thank you to my supervisors Live Steinnes Luteberget and Gøran Paulsen who I have had the privilege to work with. Thank you for believing in this project and being to great help throughout the whole process. I have learned a lot from you through interesting discussions and great feedback. I feel like you have shown interest in this project and cooperated with me to make it work.

Also, a big thanks to the participants in this study who have dedicated a lot of time to this project. You have together with showing your interest in the study made me even more motivated.

Emma Hald

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1. Introduction

When preparing for a competition, many factors need to be considered. It is important to have a structured plan, and to obtain continuity. In most sports the margins between winning and losing are small. The outcome of the competition is therefore more complex than just the amount of training and recovery over a longer period of time. Elite athletes typically engage in long-term training programs to improve muscular performance (Baker, 2001). However, while this type of training traditionally have been used to elicit chronic adaptations in strength and power, researchers have also identified that resistance training stimuli may have a positive, acute effect on performance (Cook, Kilduff, Crewther, Beaven, & West, 2014; Raastad & Hallen, 2000; Saez Saez de Villarreal, Gonzalez-Badillo, & Izquierdo, 2007; Tsoukos, Veligekas, Brown, Terzis, & Bogdanis, 2018).

In addition to the potentiation seen within minutes after performing a maximal or near maximal contraction (Seitz & Haff, 2016), researchers have also identified a delayed potentiation from one to 72 hours after a previous resistance training (RT) session (often called a priming session) (Ekstrand, Battaglini, McMurray, & Shields, 2013; Raastad & Hallen, 2000; Saez Saez de Villarreal et al., 2007; Tsoukos et al., 2018). This potentiation is induced by the contractile history of the muscles (Boullosa, Abreu, Beltrame, & Behm, 2013). However, this contractile history can also induce fatigue (Linnamo, Hakkinen, & Komi, 1998; Raastad & Hallen, 2000). Even though there are scientific studies showing a delayed potentiation after a priming session (Ekstrand et al., 2013; Raastad & Hallen, 2000; Saez Saez de Villarreal et al., 2007; Tsoukos et al., 2018), few studies have yet managed to find a potentiation in weightlifting performance (Chen et al., 2011; Fry, Stone, Thrush, & Fleck, 1995).

Based on the current scientific literature, it could be hypothesized that the outcome of a competition could be affected by the training routines the day before and on the day of a competition. In Olympic weightlifting (weightlifting) there are often few kilograms (kg) separating the winner from the second place. A delayed potentiation could therefore potentially be the difference between winning and not during a competition. It was early suggested that heavy loads could activate the nervous system (Verhoshansky, 1986). However, to avoid fatigue, RT is often avoided prior to competitions (Grgic & Mikulic, 2017). In earlier studies different priming sessions like heavy low-volume sessions (Cook et al., 2014; Ekstrand et al., 2013; Saez Saez de Villarreal et al., 2007), light (McCaulley et al., 2009; Saez Saez de Villarreal et al., 2007) and moderate (Mason, Argus, Norcott, & Ball, 2017; Raastad & Hallen, 2000; Saez Saez de Villarreal et al., 2007; Tsoukos et al., 2018) sessions are used. These different priming sessions have been shown to improve performance in counter movement jump (CMJ) (Cook et al., 2014; Tsoukos et al., 2018), rate of force development (RFD) (Tsoukos et al., 2018) and 1 repetition maximum (RM) (Cook et al., 2014) to mention some.

The long-term effect of strength training has received a lot of attention and is now a well-studied field. Even though there is a lot of studied theories around this field, the theories around optimal training routines the day before a competition seems to be rather more experience based. Some researchers have been studying the effect priming sessions for boosting performance (Cook et al., 2014; Ekstrand et al., 2013; Fry et al., 1995; Raastad & Hallen, 2000; Tsoukos et al., 2018). However, there are fewer studies aiming directly at specific sports (Chen et al., 2011; Cook et al., 2014; Fry et al., 1995). And even fewer studies on weightlifters (Chen et al., 2011; Fry et al., 1995).

By competing both at national and international level I have observed different training routines the day before important weightlifting competitions, and it does not seem to be a consensus among athletes and coaches on how to train the day before a competition and how different training sessions affect subsequent muscular performance. In the Norwegian sport science community, weightlifting has not been a priority. This means that a lot of the knowledge among Norwegian athletes and coaches are experienced based or based on scientific research from other counties with another organization of the sport. More research on Norwegian and Nordic weightlifters could help the Nordic countries by increasing the knowledge and thereby possibly increase the performance in competitions.

The delayed potentiation is an interesting field considering boosting performance during competitions. Previous research is showing that a delayed potentiation could be expected after a priming session compared to rest. However, recommendations regarding priming sessions for many sports including weightlifting are missing. More research is therefore needed to enhance the understanding of how the training routines before a competition affect subsequent performance. To investigate how these different priming sessions can affect weightlifting performance differently, tests relevant for weightlifting performance was used. The participants were tested in; maximal velocity in snatch and clean (weightlifting tests), force-velocity (F-v) relationship and jump height (generic tests).

The purpose of this study was therefore to investigate if different priming sessions and rest could affect the subsequent performance in weightlifting and other power movements in the lower limbs. And more precisely if a light/moderate priming session, a heavy priming session and a rest day could affect the performance differently 24 hours after a priming session in maximal velocity in snatch and clean, jump height and the F-v relationship.

1.1 Scientific Questions

Two scientific questions were defined:

1) Is there a significant difference between performance in a) maximal velocity in snatch and clean b) vertical jump height and c) force-velocity relationship 24 hours after different priming sessions and rest?

2) Is there a significant difference between performance in a) maximal velocity in snatch and clean b) vertical jump height and c) force-velocity relationship 24 hours after a high resistance priming session and a low/moderate resistance priming session?

2. Theory

2.1 Olympic Weightlifting

Olympic weightlifting has been an Olympic sport since 1896 (Olympic.org, s.a.). In weightlifting athletes compete to achieve the highest possible total weight lifted in the two lifts: snatch and clean and jerk (C&J). In snatch, a loaded barbell is pulled with a wide grip in a single movement from the ground to fully extended arms above the head, while either splitting or bending the legs. In clean a loaded barbell is pulled with a shoulder width grip in a single movement from the ground to the shoulders, while either splitting or bending the legs. The clean is followed by bending the legs and extending them as well as the arms to bring the barbell over head on fully extended arms (jerk) (iwf.net, s.a.-b). During these lifts, weightlifters achieve some of the greatest power outputs compared to other athletes (Garhammer, 1980).

2.1.1 Competitions

In a weightlifting competition, the participants have three attempts in each lift to achieve the highest possible weight lifted. All participants compete in weight categories, with ten categories for each men and women and seven for each gender in the Olympic games (iwf.net, s.a.-a). Performance are often measured in Sinclair points (now called Robi points), where performance is calculated from total weight lifted and body mass. The weigh-in of the athletes are usually done in a one-hour window, two hours before competition-start. Apart from the technical complexity of the lifts, weightlifting is not a very complex sport, with few parameters affecting performance in competition. In weightlifting there are often few kg separating the winner from the second place. During the 2019 IWF World Championships the mean difference for male and female weightlifters between first and second place was 7.7±7.8kg (2.5±2.5%). And in six of 20 weight classes only one kg separated the first and second place (IWF.net, 2019). A delayed potentiation could therefore potentially be the difference between winning and not during a competition.

2.1.2 Programming

To perform physically, weightlifters engage in long term training programs often focusing on maximal strength in the beginning and speed and technique in the end of the programmed period. This type of programming is often called a traditional linear periodization (Poletaev, 1995). However, the scientific research regarding weightlifting programming is not extensive (Gonzalez-Badillo, Izquierdo, & Gorostiaga, 2006; Hoffman J.R., 2004; Poletaev, 1995; Stone, Pierce, Sands, & Stone, 2006). In weightlifting, volume and intensity (resistance) have always been important factors. Since 1970 the volume have been a parameter based on the amount of sets and repetitions performed per day, week, month or year (Poletaev, 1995). And the intensity being defined as the weight lifted relative to the current 1RM (Medvedev, 1971).

2.1.3 Parameters of Performance

Physical performance in weightlifting is determined mostly by some skills, which are summed up in technique, strength and power. In weightlifting, strength is highly correlated with weightlifting performance (Stone et al., 2005). Also, technique, velocity and acceleration are important parameters of performance (Liu et al., 2018; Sato, Sands, & Stone, 2012). These parameters are often used together with barbell trajectory, angular velocity of joints, barbell height and absolute and relative work (Akkus, 2012; Chiu, Wang, & Cheng, 2010). The maximal velocity in snatch during the second pull in maximal lifts range between 1.65 and 2.28 m/s (Akkus, 2012; Chiu et al., 2010; Garhammer, 1991; Gourgoulis, Aggelousis, Mavromatis, & Garas, 2000). In clean the maximal velocity during maximal lifts in the second pull range between 0.88 and 1.73 m/s (Garhammer, 1985, 1991). In weightlifting the first pull have been found to be more strength based and the second pull to be more power based (Akkus, 2012; Chiu, Wang, & Cheng, 2010). Therefore the highest velocities are usually seen during the second pull (Chiu et al., 2010).

2.1.4 Pulling Phases

Researchers have divided the pull in snatch and clean into different phases (Baumann, Gross, Quade, Galbierz, & Schwirtz, 1988; Garhammer, 1980; Gourgoulis et al., 2000; Harbili & Alptekin, 2014). The jerk is also divided into different phases but will not be examined in this text. The different phases is calculated from the change in direction of the knee angle and the height of the barbell (Table 2.1.4) (Baumann et al., 1988; Gourgoulis et al., 2000). In science the snatch and clean starts when the barbell leaves the floor (lift off) and ends when the barbell is cached either over head in snatch or on the shoulders in clean (Reiser, 1996) (the fifth phase).

Table 2.1.4: The first five phases of the snatch pull. Determined by the change of direction of the knee angles and the height of the barbell (Baumann et al., 1988; Gourgoulis et al., 2000; Harbili & Alptekin, 2014).

Phases of the snatch	Description
The first pull	From barbell lift-off until the first maximum knee extension
The transition phase	From the first maximum knee extension until the first maximum knee flexion
The second pull	From the first maximum knee flexion until the second maximum extension of the knee
The turnover under the barbell	From the second maximum extension of the knee until the achievement of the maximum height of the barbell
The catch phase	From the achievement of the maximum height of the barbell until stabilization in the catch position

2.2. Post Activation Potentiation

Resistance training is often avoided closer to an important competition (Grgic & Mikulic, 2017; Swinton, Lloyd, Keogh, Agouris, & Stewart, 2012). However, performing maximal or near maximal muscle contractions within minutes of performing a strength-power activity has been shown to improve performance. This phenomenon is called post-activation potentiation (PAP) (Seitz & Haff, 2016). PAP is an acute effect of the recent contractile history of a muscle. "PAP is an increase in muscle twitch and low-frequency tetanic force after a "conditioning" contractile activity" (Sale 2002 p. 1). PAP can be induced by both ballistic movements as well as heavy load resistance movements (West, Cunningham, Crewther, Cook, & Kilduff, 2013). However, PAP have been shown to only work in a short timeframe of only 16 to 20 minutes (Kilduff et al., 2008).

Weightlifters need to perform over a longer period of time. In competition, each group usually last ~1-2 hours dependent of the number of participants in the group. And using PAP to boost performance in a weightlifting competition could therefore be difficult.

2.3. Delayed Potentiation

Some researchers are suggesting another window of potentiation. This is a delayed potentiation (Harrison, James, McGuigan, Jenkins, & Kelly, 2019) effect that occurs between 1 and 72 hours after muscle contractions. The potentiation found after a priming session could be due to an absence of fatigue and a delayed enhancement of explosive performance similar to a taper (Tsoukos et al., 2018). To perform technically challenging lifts, it is important to perform both physically and mentally. The delayed potentiation have been found to affect both of these factors (Cook et al., 2014; Fry et al., 1995; Tsoukos et al., 2018). The recent scientific research has found heavy low volume and low/moderate ballistic priming sessions to enhance subsequent neuromuscular performance. The effects have been found after 6 hours (Cook et al., 2014; Ekstrand et al., 2013), 24-48 hours (Raastad & Hallen, 2000; Tsoukos et al., 2018), and up to 72 hours (Chen et al., 2011). These studies are among other things, showing an increased performance in vertical jump (Cook et al., 2014; Raastad & Hallen, 2000; Tsoukos et al., 2018), RFD (Tsoukos et al., 2018) and maximal strength (Cook et al., 2014) (Table 2.3). These findings could be relevant for weightlifters regarding the strength and power demand in the sport.

It is suggested that there are responders and non-responders to a priming session (Fry et al., 1995). Strength level seems to influence the change in physical performance (Seitz, de Villarreal, & Haff, 2014; Tillin & Bishop, 2009) seen after a priming session. In addition, Fry et al. (1995) have found more fearful athletes to respond better to a priming session. The delayed potentiation can therefore be highly individual between individuals. Fry et al. (1995) was probably the first to suggest a delayed potentiation. By examining the effects of a priming session in competitive weightlifters an enhanced performance was found 5.5 hours after a priming session in six of the nineteen weightlifters included in the study (Fry et al., 1995). Since Fry et al. (1995) several other investigations have also found an enhanced performance after a priming session (Table 2.3).

Table 2.3: Overview of different studies of effects of a priming session. RSI = reactive strength index, MIF = maximal isometric force, RFD = rate of force development, CMJ = counter movement jump, SJ = squat jumps. VJ = vertical jumps. ↑= improved performance ↓ = reduced performance

Study	Type of Priming session	Hours / minutes before testing	Variables	Significant results
(Raastad & Hallen, 2000)	Front squat: 70% 3RM + 100% 3RM (3x3) Leg extension: 70% 3RM + 100% 3RM (3x6) for both	5, 15 min 3, 7, 11, 22, 26, 30, 33h	SJ	100% protocol: 15min– 12% ↓ SJ, 22h– significant ↓ 70% protocol: 3,7,11h – ↑ SJ. 22-33h – 5% ↑ SJ
(Tsoukos et al., 2018)	Jump squats: 40% 1RM (5x4)	24 h 48 h	CMJ, RSI, MIF, RFD,	24h - 5% ↑ CMJ + 10,7*% ↑ RSI + 18,3%↑ RFD_{0-100} 48h - 3% ↑ CMJ + 9,8%↑ RFD_{0-100}
(Cook et al., 2014)	Bench press + Back squat: 80%, 90%, 100% of 3RM (3x3)	6h	Squat, Sprint (40m), CMJ	After weight protocol – 4,1%↑ squat + 1,3% ↑ sprint + 2,7% ↑ CMJ After sprint protocol – 0,7% ↑ sprint
(Chen et al., 2011)	2h weightlifting program 60-95% of maximal effort.	3, 24, 48, 72h	Squat, dead lift, front squat	72h – significant improvement in squat + dead lift
(Ekstrand et al., 2013)	Back squat: 85% of 1RM (1x6) + 1x to failure at 85% of 1RM. Power clean: to fatigue in sets of 4 repetitions.	4-6h	Backward overhead shot throw	2,6% ↑ (11,76m vs. 11,46m)
(Mason et al., 2017)	Banded back squat + banded bench press: (4x3)	1.75h	Bench press, CMJ	↑ Bench press peak power + velocity +peak force ↓ CMJ peak power + velocity +peak force

(Saez Saez de Villarreal et al., 2007)	CMJ: 30-40% of 1RM (3x5). Half squat: 80% (2x4) 90% (2x2) 95% (2x1) 30% (3x5) Drop jump: body weight (3x5).	6h	CMJ, Drop jump	↑ CMJ and DJ after all conditions.
(McCaulley et al., 2009)	Squat jump: unweighted (8x6)	24, 48h	Isometric squat peak force, + Isometric squat RFD	↑ after 24 and 48h
(Fry et al., 1995)	Clean pulls: 85% 1RM (5x3) Snatch pulls 85% 1RM (3x3)	5.5h	VJ, snatch, C&J	Responders: ↑ VJ. ↑ snatch. ↑C&J. Non-responders: ↓VJ. ↓ snatch. ↓C&J

2.3.1. Fatigue

Through the current scientific literature improvements are found in power and maximal strength, which is highly relevant for many sports, including weightlifting. However, another possible consequence of a RT session is fatigue (Raastad & Hallen, 2000). The balance between fatigue and a potentiation determines the contractile response (Tillin & Bishop, 2009). And it is therefore important to understand how different factors in training are affecting this balance. The fatigue after a RT session is caused by a central or periphery fatigue, and thereby a decrease in neural drive of the muscle fiber force production (Newham, Mccarthy, & Turner, 1991). Fatigue is defined as a "reduction in the force-generating capacity of the total neuromuscular system, regardless of the force required in any given situation" (Biglandritchie, 1984). The muscular fatigue may persist from one hour and up to seven days (Ide et al., 2011; Linnamo et al., 1998). A decline in velocity have been used as an indicator of neuromuscular fatigue (Sanchez-Medina & Gonzalez-Badillo, 2011). Earlier studies have been focusing on the isometric and isokinetic velocity when investigating fatigue (Newham et al., 1991). However, newer studies have been using the velocity of dynamic contractions to assess fatigue. For instance, vertical jump performance have been used as an easily measured indicator of fatigue and potentiation (Raastad & Hallen, 2000; Tsoukos et al., 2018). In concentric contractions a higher frequency is needed to induce a given percentage of maximum force compared to isometric contractions (Abbate, Sargeant, Verdijk, & de Haan, 2000). The velocity of the contraction can also cause a greater amount of fatigue after a RT session (Ide et al., 2011). Possibly making more explosive athletes more vulnerable for fatigue.

2.3.2 Mechanisms who Explain the Delayed Potentiation

There is not extensive research regarding the responses to a priming session. Among others, individual strength level seems to influence the change in physical performance (Seitz et al., 2014; Tillin & Bishop, 2009). Mechanical stiffness has been proposed as a possible mechanism to explain the potentiation seen after a priming session (Tsoukos et al., 2018). Stiffness is defined as the resistance of the body segment, joint, or series of joints to changes in length (Brughelli & Cronin, 2008). Mechanical stiffness has shown to increase immediately after a RT session and after a short-term period of strength and power training (Brughelli & Cronin, 2008). Mechanical stiffness is also correlated with jump height and isometric rate of torque development (Bojsen-Moller, Magnusson, Rasmussen, Kjaer, & Aagaard, 2005). Also, Increased fiber sensitivity to calcium ions have been suggested to play a role in the delayed potentiation (Sale, 2002; Tillin & Bishop, 2009). Other reasons for the potentiation seen in high level athletes may be due to changes in hormones like testosterone and cortisol. Some studies are showing a 15,1% increase in testosterone after jumping protocol on healthy men (Volek, Kraemer, Bush, Incledon, & Boetes, 1997). In elite athletic populations testosterone have shown to predict performance (Cook & Crewther, 2012; Crewther, Cook, Cardinale, Weatherby, & Lowe, 2011). Others are showing a negligible response of testosterone levels after power-type RT sessions in men and women (Linnamo, Pakarinen, Komi, Kraemer, & Hakkinen, 2005; McCaulley et al., 2009). Free testosterone have together with being linked to better acute physical performance in elite athletes, also been linked to better motivation, readiness to perform and reduced fear (Crewther et al., 2011).

2.3.3 Volume, Resistance and Exercises to Induce Potentiation

Increased volume seems to be a key indicator to acutely induce a greater metabolic stress in the muscles (Cintineo et al., 2018). As repetition number approaches failure, time of recovery have shown to significantly increase (Sanchez-Medina & Gonzalez-

Badillo, 2011). High loaded, low volume priming sessions have been found to elict the delayed potentiation, and to significantly improve neuromuscular performance (Cook et al., 2014; Ekstrand et al., 2013; Saez Saez de Villarreal et al., 2007). For high resistance priming sessions a low volume (3-6 repetitions) is favorable in inducing a delayed potentiation (Saez Saez de Villarreal et al., 2007; Tsoukos et al., 2018). Improvements have also been found in low and moderate sessions (30-70% of 1RM) (Mason et al., 2017; Raastad & Hallen, 2000; Saez Saez de Villarreal et al., 2007; Tsoukos et al., 2018). During these sessions, ballistic movements cause a greater potentiation (Mason et al., 2017; Saez Saez de Villarreal et al., 2007; Tsoukos et al., 2018). And generally, high velocities seem to be favorable in resistance priming (Saez Saez de Villarreal et al., 2007). In the light and moderate ballistic sessions, a higher (15-20 repetitions) number of repetitions have been found to induce a delayed potentiation (Saez Saez de Villarreal et al., 2007; Tsoukos et al., 2018). No improvements are found in sessions with a load <30% of 1RM (McCaulley et al., 2009; Saez Saez de Villarreal et al., 2007). The most common types of exercises in programs inducing neuromuscular potentiation is squats (Cook et al., 2014; Ekstrand et al., 2013; Mason et al., 2017; Raastad & Hallen, 2000; Saez Saez de Villarreal et al., 2007) and loaded squat jumps (Saez Saez de Villarreal et al., 2007; Tsoukos et al., 2018). Pulling exercises (snatch pull and clean pull) (Fry et al., 1995), power clean (Ekstrand et al., 2013) and bench press (Cook et al., 2014; Mason et al., 2017) are also used. Improvements are found with both one (Saez Saez de Villarreal et al., 2007; Tsoukos et al., 2018) and several (Cook et al., 2014; Ekstrand et al., 2013; Fry et al., 1995; Raastad & Hallen, 2000) exercises included in the priming sessions.

2.4 Force-velocity Profile

Ballistic performance is not only a result of maximal power but also the F-v relationship (Samozino, Rejc, Di Prampero, Belli, & Morin, 2012). The force-velocity (F-v) relationship is giving us information about the mechanical properties of the neuromuscular system (Table 2.4) (Samozino et al., 2012). It could therefore be useful as a tool for describing different properties of the muscles. The F-v relationship are measured using different methods. Some of the methods are: squat jump heights with increased resistance (Giroux, Rabita, Chollet, & Guilhem, 2016), sprint with measuring horizontal ground reaction forces (Rabita et al., 2015), leg extension (Bobbert, 2012) and leg press with pneumatic resistance (Colyer, Stokes, Bilzon, Holdcroft, & Salo, 2018). The F-v relationship describes changes in external force generation and power output with increasing movement velocity. Obtaining high movement velocities at high forces is highly relevant to weightlifting performance. The F-v relationship are often described by three parameters where maximal force at null velocity = F_0, maximal power = P_{max} and maximal velocity at zero load = v_0. These parameters encompass individual muscular mechanical properties, morphological factors, and neural mechanisms (Table 2.4) (Cormie, McGuigan, & Newton, 2011; Samozino et al., 2012). The maximal force is produced with no velocity (or eccentric movements) and the maximal velocity is produced under zero load (Samozino et al., 2012). Some place in the middle of the F-v curve were the sum of F·v is highest we will achieve the maximal power output (F·v = P).

Table 2.4: Overview of mechanical factors influencing the F-v relationship (Cormie et al., 2011; Samozino et al., 2012).

Muscle mechanical properties	**Morphological factors**	**Neural mechanisms**
- Intrinsic F-v	- cross- sectional area	- motor unit recruitment
- Length-tension relationship	- fascicle length	- firing frequency
- Rate of force development	- pennation angle	- motor unit synchronization
	- tendon properties	- intermuscular coordination

It is possible for different athletes to achieve the same power with different contribution from force and velocity (Samozino et al., 2012). A F-v profile test can help athletes to better understand their neuromuscular weaknesses and strengths. For athletes competing in sports where power is an important factor, understanding the F-v relationship can spot weaknesses in the total power production. By improving the weakness of either strength or velocity the total power production can be improved and thus possibly the performance. In science it does not seems like the F-v relationship in combination with weightlifting performance have been used. However, it could possibly be an appropriate method to monitor performance regarding power production in the lower limbs. However, in earlier research the F-v relationship has failed to predict changes in CMJ (Baena-Raya, Sanchez-Lopez, Rodriguez-Perez, Garcia-Ramos, & Jimenez-Reyes, 2020). Vertical jumps are more widespread in monitoring weightlifting performance (Canavan Paul K.; Garrett, 1996; Carlock et al., 2004). However, in vertical jumps, zero load is often used, which not necessarily is relevant for weightlifting.

2.5 Vertical Jump

Vertical jumps are strongly correlated with weightlifting performance (Canavan Paul K.; Garrett, 1996; Carlock et al., 2004). And therefore, vertical jumps can be a valuable tool in monitoring performance in weightlifting (Carlock et al., 2004). Achieving the highest possible height by the body´s center of gravity in vertical jump height performance is to achieve the highest possible vertical velocity at take-off (Dowling & Vamos, 1993). The vertical velocity at take-off are determined by morphological and neuromuscular properties (Cormie et al., 2011). Vertical jump heights are often used to measure level of fatigue (Raastad & Hallen, 2000; Rodacki, Fowler, & Bennett, 2002). Both SJ (Raastad & Hallen, 2000) and CMJ (Cook et al., 2014; Tsoukos et al., 2018) are used in priming sessions. The CMJ are one of the most frequently used tests to monitor neuromuscular status (Claudino et al., 2017; Loturco et al., 2015). And CMJ are a good indicator of fatigue or potentiation (Cormie, McBride, & McCaulley, 2009; Coutts, Reaburn, Piva, & Rowsell, 2007). In monitoring fatigue, average jumping height seems to be a better indicator of fatigue compared to the highest jumping height (Claudino et al., 2017). The fatigued muscles seem to have lower peak angular velocity and peak power during the propulsive part of the vertical jump. However, fatigued and not fatigued vertical jumps have shown to result in similar muscle activation measured with electromyography (Psek & Cafarelli, 1993). Rodacki et al. (2002) suggested that declined vertical jump performance is mainly affected by fatigue in knee extensors, rather than knee flexors (Rodacki et al., 2002). In the study by Raastad & Hallen (2000) the SJ was potentiated three to 33 hours after a 70% of 1RM protocol. After a 100% of 1RM protocol the SJ was potentiated after 33 hours. Therefore, it seems likely that a potentiation in jumping height would occur after a RT session, but the fatigued time will be increased with increased resistance and volume (Cintineo et al., 2018).

3. Methods

3.1 Study Design

A within participant repeated measure design was used in this study (outlined in Figure 3.1). Three different conditions were compared: low/moderate resistance priming session (LR), high resistance priming session (HR) and rest day (CON). A combination of the different conditions was combined with a participant number before participants were recruited. All participants met on seven occasions, one familiarization, two priming sessions, one rest day and three test days. To minimize influence from training between conditions, the participant was encouraged to repeat the same training program for all weeks.

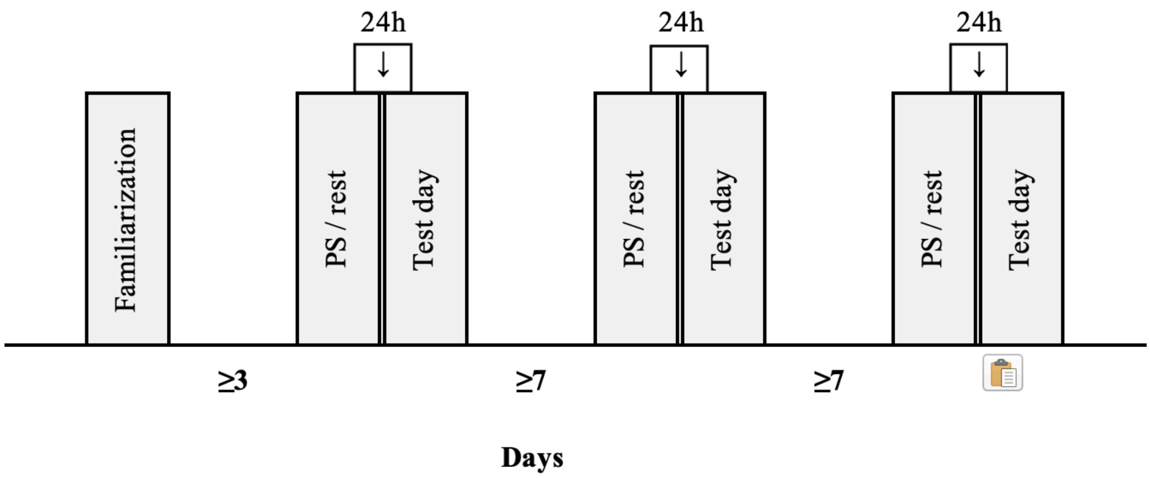

Figure 3.1: Overview of the testing period. On the day of priming session (PS) or rest, participants were informed by attendance of whenever they were going to perform a low/moderate resistance session (LR), high resistance session (HR) or rest day (CON). Twenty-four hours post condition a test day to measure performance in generic and weightlifting test were completed.

The study was approved by the Norwegian Centre for Research Data (NSD) and the ethical committee at the Norwegian School of Sport Sciences. Participation in the project required time and effort form the participants. During tests the participant did maximal and submaximal contractions, which can be unpleasant. However, the participant was not exposed to any further risk than during their regular training regime. All information about the participant was de-identified and held in an identification and enrolment log. Due to the schools' ethical policy, the identification and enrolment log will be kept up to five years after the study is finished, and thus, the data can be checked for verifiability. After these five years the data will be anonymized.

3.2 Participants

Seven male (n=3) and female (n=4) weightlifters of different levels (age 24.6 ± 4.7) were recruited through social media and direct contact (Table 3.2). All participants signed a written consent on the familiarization day (attachment I). Because of difficulties in recruiting weightlifters at a high level, all weightlifters between 18 and 35 years old who applied was tested. All participants answered a brief questionnaire about their performances (attachment II). The original inclusion criterion was not used. The participant ranged between weightlifters competing at international level, national level (n=6) and non-competing (n=1). However, all participants performed a stable and proper technique. In addition to the questionnaire, body weight was measured all test days using the HUR force platform (FP4, HUR Labs, Finland). The body weight was measured to calculate vertical jump height.

Table 3.2: Participant characteristics. mean±SD (n=7). Sinclair: n=6 (minus one participant without any competitions yet)

Characteristics	mean±SD
Sex	4 female 3 male
Age	24.6±4.7
Bodyweight (kg)	71.5±10.8
Sinclair (female, n=3)	191.7±40.1
Sinclair (male, n=3)	318.6±48.9
Years of lifting	5.1±4.0

3.3 Experimental Approach

The experimental protocol involves two conditions (Table 3.3) and one rest day. All experimental protocols were completed together with the researcher. Participants were informed by attendance of which condition they were going to perform. This was to avoid different daily routines based on condition type. On the rest day participants received a message two hours before testing. Three different conditions were compared:

low/moderate resistance priming session (LR), high resistance priming session (HR) and rest (CON). During LR, a light session (up to 60% of 1RM) focusing on power was performed. During this session the power snatch and power clean + jerk was used together with low-loaded counter movement jumps. The HR focused on few lifts at 80, 85 and 90% of 1RM in snatch, C&J and front squats. The total volume varied because participants needed a different number of repetitions building up to the right percentages described in Table 3.3. During CON the participant were asked to take a day off without any kind of training or abnormal activities.

Table 3.3: Showing low/moderate and high resistance priming sessions. Rep + rep = clean + jerk. # = percentage of 1RM squat. Power snatch and power clean is calculated from 1RM snatch and clean.

Low/moderate Resistance Priming Session (LR)

Exercise	%1RM	Rep x set	%1RM	Rep x set	%1RM	Rep x set
Power snatch	40	2 x 2	50	2 x 2	60	2 x 2
Power clean + jerk	40	2+2 x 2	50	2+2 x 2	60	2+2 x 2
Loaded CMJ	20#					

High Resistance Priming Session (HR)

Exercise	%1RM	Rep x set	%1RM	Rep x set	%1RM	Rep x set
Snatch	85	1 x 2	90	1 x 1		
Clean and jerk	85	1+1 x 2	90	1+1 x 1		
Front squat	85	2 x 1	90	2 x 2		

All participants completed a familiarization session, three different conditions and three test days (Figure 3.1). The familiarization session was used to determine 1RM leg press in a pneumatic leg press and for the participants to get familiarized with the testing protocol. The participants also signed a written consent and answered a brief questionnaire. Current 1RMs in snatch, C&J, squat and front squat was registered, but not tested. Minimum three days after the familiarization session, participants completed their first condition. The order of the different conditions was set before recruiting participants. And the combinations of different conditions were randomized to the participants. This was to ensure that different combinations of conditions were used. Twenty-four hours after each condition a test day was completed to measure performance in generic and weightlifting tests.

3.4 Tests

The test day was always completed 24 hours after a previous condition. Testing consisted of both generic and weightlifting tests. Where the generic tests were a F-v profile test in a pneumatic leg press and a vertical jump test with SJ and CMJ. The weightlifting tests were video recordings measuring maximal velocity in snatch and clean. All tests were performed in this order after a five-minute cycling for a general warm-up. The total duration of the test days ranged between 60 and 90 minutes. Mostly influenced by the amount of warm-up lifts performed before the snatch and C&J.

3.4.1 Warm-up

The participant did standardized warm-ups to exclude the possible effects of different warm-up routines on performance (Barnes, Petterson, & Cochrane, 2017). The same standardized warm-up of five minutes ergometer cycling was used for both the familiarization day, the condition days and the test days. A more specialized warm-up was performed before the different tests and training sessions. The warm-ups before the 1RM test and F-v profile test in pneumatic leg press is described further in the next paragraphs. The vertical jump test did not use a warm-up due to possible fatigue. Before the video recordings of snatch and C&J a basic dynamic stretching warm-up without the barbell was used before snatch. Before the snatch the participant also performed a more specialized warm-up with the barbell, consisting of five muscle snatch, five overhead squats and five strict press behind the neck. Before the clean and jerk, the participant did a similar warm-up with the barbell, consisting of five muscle cleans, five front squats and five strict press. After the more specific warm-ups the participant chose their own warm-up consisting of lifts up to 80% snatch and clean and jerk. They repeated the same routine for every test day.

3.4.2 Weightlifting Tests

To measure peak velocity in snatch and clean the Olympic lifts were video recorded. Lifts at 80, 85 and 90% of estimated 1RM was recorded in slow motion (240 Hz) with an iPhone 8 camera. There have been several studies using video to analyse the kinematics of the snatch and C&J and it is a well-used method for analyzing Olympic lifts (Akkus, 2012; Chiu et al., 2010; Garhammer, 1991). Mostly, 50 Hz in sampling frequency are used for the video recordings (Akkus, 2012; Chiu et al., 2010; Harbili, 2012; Liu et al., 2018), Chiu et al. 2010 used a high-speed camera at 120 Hz. With newer technology and easier access to a greater sampling frequency, the iPhone camera with 240 Hz was used. The high sampling frequenzy makes it easier to measure the reflective marker correctly without the reflective marker moving too much between pictures. The participants were recorded in the sagittal plane, using a two-dimensional method. Chiu et al. 2010 found a very small displacement of the barbell in the media lateral horizontal direction during lifts. Making a two-dimensional method to analyze kinematics in the sagittal plane appropriate during weightlifting movements if the initial position of the barbell is similar for each lift. The snatch and C&J were filmed on an Eleiko lifting platform using Eleiko (Halmstad, Sweden) Olympic equipment. To calibrate the two-dimensional area, two calibration sticks of one meter was placed on the platform (Figure 3.4.2). To determine the two-dimensional kinematic data from the barbell, an orange mark with a reflective marker was placed on the end of the barbell to track barbell path and calculate barbell velocity. The flash on the iPhone was used to better observe the reflective marker.

Figure 3.4.2: Showing the setup for recording snatch and C&J. This photo is used in consent with the test person.

3.4.3 Pneumatic Leg Press

On the familiarization day the 1RM leg press test were performed on a Keiser pneumatic leg press apparatus (Keiser Pneumatic Leg Press A420, Keiser Corporation, Fresno, CA, USA). Keiser Pneumatic leg press is a testing and training apparatus using a pneumatic resistance. The leg press measures force, velocity and calculating maximal power with excellent reliability according to unpublished data by Olympiatoppen (Coefficient of variation, CV% = 4.3±0.7). The pneumatic leg press was used as a tool for the 1RM test and the force velocity profile test. The seat position was individually adjusted to a position with the femur in a vertical position in the beginning of the concentric contraction.

3.4.3.1 One Repetition Maximum

The 1RM protocol began with a warm-up consisting of ten repetitions, seven repetitions and three repetitions at increasing resistance followed by single repetitions at increasing resistance until failure. The highest successful lift was defined as their 1RM. The pause between sets including warm-up sets was approximately two minutes.

3.4.3.2 Force Velocity Profile

The force velocity profile test was conducted on the familiarization day and all three test days. The F-v relationship test is using a protocol in the Keiser software program. The seat position was adjusted to the same position as the 1RM leg press test. The protocol included two warm-up repetitions followed by single repetitions at increasing resistance. The software is using the previously measured 1RM and divides it into ten repetitions, starting at ~15% of 1RM for the first repetition. The load will then automatically increase for each repetition until it reaches 1RM at the tenth repetition. The rest-pauses get progressively longer with increasing loads (~5-30 sec). From this test we gained information about the power production and the force-velocity relationship for the left and right leg and the maximal power. The maximal power was defined as the mean maximal power between the left and right leg. The maximal power was calculated from average by the Keiser software. The participants were verbally encouraged during the test and was repeatedly told to perform the contraction as fast as possible.

3.4.4 Vertical Jumps

The vertical jump tests were performed on the familiarization day and all three test days using a portable force platform with a sampling rate of 1200Hz (HUR Labs, FP4, Tampere, Finland). The HUR software calculates jump height using take-off velocity, which in turn is calculated with the impulse-momentum method (HUR-Labs, 2014). The force platforms are a well-known and standardized method for measuring jump height. Calculations from time in air have shown to produce good reliability (Aragón, 2000). Force platforms are also used in the validation of other jumping methods (Dobbin, Hunwicks, Highton, & Twist, 2017) and even as a gold standard (Toft Nielsen, Jorgensen, Mechlenburg, & Sorensen, 2019). The portable force platforms are also showing good reliability and validity when compared to rigid platforms in vertical jumps (Peterson Silveira et al., 2017; Walsh, Ford, Bangen, Myer, & Hewett, 2006).

The participants were both tested in counter movement jump (CMJ) and squat jump (SJ). The SJ starts in a squatting position where the participants jumps as high as possible without countermoving (Anderson & Pandy, 1993). In the CMJ the participant starts in a neutral position. In both jumps the results were invalid if the participants hands were not placed on the hips throughout the movement. In SJ the results were not valid if the graph showed a countermovement before the concentric contraction. The participant completed three jumps in SJ and CMJ, without a specific warm-up. In cases where there were invalid attempts or a large increase in jump height more repetitions was allowed until they had minimum two approved jumps.

3.4.5 Vmaxpro

The Vmaxpro was used as a supplement to the video analysis where peak velocity was measured. The Vmaxpro is a three-axial accelerometer which can be placed on the barbell with the help of a magnet and a strap. The Vmaxpro can be synchronized with a video recording (from an iPad or iPhone) and measures acceleration in three axes together with sensor orientation in space (vmaxpro.de). This device was included as an alternative measuring method to investigate the validity of Vmaxpro.

3.5 Analysis

3.5.1 Video Analysis

Snatch and clean was used in the video analysis. Peak velocity was calculated from the time and position of the barbell using a software called Tracker 5.1 (Tracker version 5.1.2, Douglas Brown, Open Source Physics, USA). In the analyses the video was cut in the beginning of the first pull (lift off) and the end of the top pull right before catching the barbell (fifth phase). The jerk was not analyzed. The same analysis was done several times to ensure good reliability. In Tracker 5.1 the frame was calibrated with measuring both calibration sticks followed by defining and automatically tracking the reflective marker. From this information tracker 5.1 could calculate velocity. All data was copied to Microsoft Excel 16.35 (Microsoft, Redmond, USA) where the peak velocity and maximal velocity was found and calculated. First the peak velocity was found. Subsequently the maximal velocity was defined as the mean between the peak velocity and the two upper and lower values.

3.5.2 Other Data Analysis

Data was analyzed in Microsoft Excel 16.35 (Microsoft, Redmond, USA), and IBM SPSS Statistics 24 (International Business Machines, New York, USA). In SPSS all box plots were observed to make sure no outliers or extremes were because of human error in plotting data. Despite of mostly normally distributed data and because of the small selection, non-parametric tests were used. In this case a Friedman-test. The level of significance was set to $p< 0.05$ for all tests. In Microsoft Excel, a Pivot table was used for analyzing. Plotting values and organizing individual results. Individual results are shown in figures made in Microsoft excel. The data is presented as mean ± standard deviation and mean change in percentage ± standard deviation in percentage. All data are plotted into a performance index by ranking each test from 1-3 with the best test result being 1 in each test.

4. Results

4.1 Subjects

Seven Olympic weightlifters participated in this study (4 female and 3 male). Results are summed up in Table 4.1. Five participants performed all tests, while two (participant 4 and 7; P4 and P7) were only able to complete two (of three) test days. Participant 4 and 7 are therefore excluded in results where all tests are needed. All participants are included in the figures, but P4 and P7 have missing values. All percentages are calculated from 1RM.

*Table 4.1: Results from all tests. Mean±SD. *significant difference from HR (p=0.05)*

	CON (n=6)	HR (n=6)	LR (n=7)
Pneumatic Leg Press (W/kg)	21.4±5.2	22.0±5.4	21.3±5.5
Pneumatic Leg Press (W)	1575±608	1633±628	1615±659
Pneumatic Leg Press (F/kg)	33.6±5.0	33.1±4.5	33.2±4.6
Pneumatic Leg Press (F)	2445±675*	2387±687	2405±627
Pneumatic Leg Press (m/s)	2.4±0.2	2.5±0.2	2.4±0.3
Squat Jump (cm)	34.3±9.8	33.0±12.8	35.6±10.5*
Squat Jump (W)	4009±1323	3871±1436	3982±1327
Counter Movement Jump (cm)	40.2±13.5	39.2±13.0	40.0±12.5
Counter Movement Jump (W)	3874±1394	3806±1433	3834±1287
Snatch 80%	2.18±0.1	2.20±0.1	2.24±0.1
Snatch 85%	2.11±0.1	2.15±0.1	2.15±0.1
Snatch 90%	2.09±0.1	2.11±0.1	2.08±0.1
Clean 80%	1.76±0.2	1.72±0.1	1.78±0.1
Clean 85%	1.75±0.1	1.70±0.1	1.75±0.1
Clean 90%	1.70±0.1	1.72±0.1	1.73±0.1

4.2 Maximal Velocity in Snatch and Clean

Even though LR showed the highest mean velocity at 80% it showed the lowest velocity at 90%. In snatch and clean, changes in maximal velocity between conditions were not significant. Individual performances are outlined in Figure 4.2. In snatch 80% the mean difference from CON to LR was 3.5±5.4% ($p=0.18$), the mean difference from CON to HR was 1.0±5.2% ($p=0.32$), and the mean difference from HR to LR was 2.3±6.3% ($p=0.41$). In snatch 85% the mean difference from CON to LR was 2.2±4.1% ($p=0.41$), the mean difference from CON to HR was 0.8±4.4% ($p=0.66$), and the mean difference between HR and LR was 0.5±5.0% ($p=1.00$). In snatch 90% the mean difference from CON to LR was -0.4±2.7% ($p=1.00$), the mean difference from CON to HR was 0.6±6.3% ($p=0.66$), and the mean difference from HR to LR was -0.5±4.2% ($p=1.00$). In clean 80% the mean difference from CON to LR was 0.4±4.3% ($p=0.41$), the mean difference from CON to HR was -2.2±10.0% ($p=0.18$), and the mean difference from HR to LR was 3.1±8.8% ($p=0.41$). In clean 85% the mean difference from CON to LR was -1.0±3.3% ($p=1.00$), the mean difference from CON to HR was -2.4±6.8% ($p=0.18$), and the mean difference from HR to LR was 2.2±5.4% ($p=1.00$). In clean 90% the mean difference from CON to LR was 1.4±6.6% ($p=1.00$), the mean difference from CON to HR was 1.6±5.7% ($p=0.32$), and the mean difference from HR to LR was -0.8±4.4% ($p=0.66$).

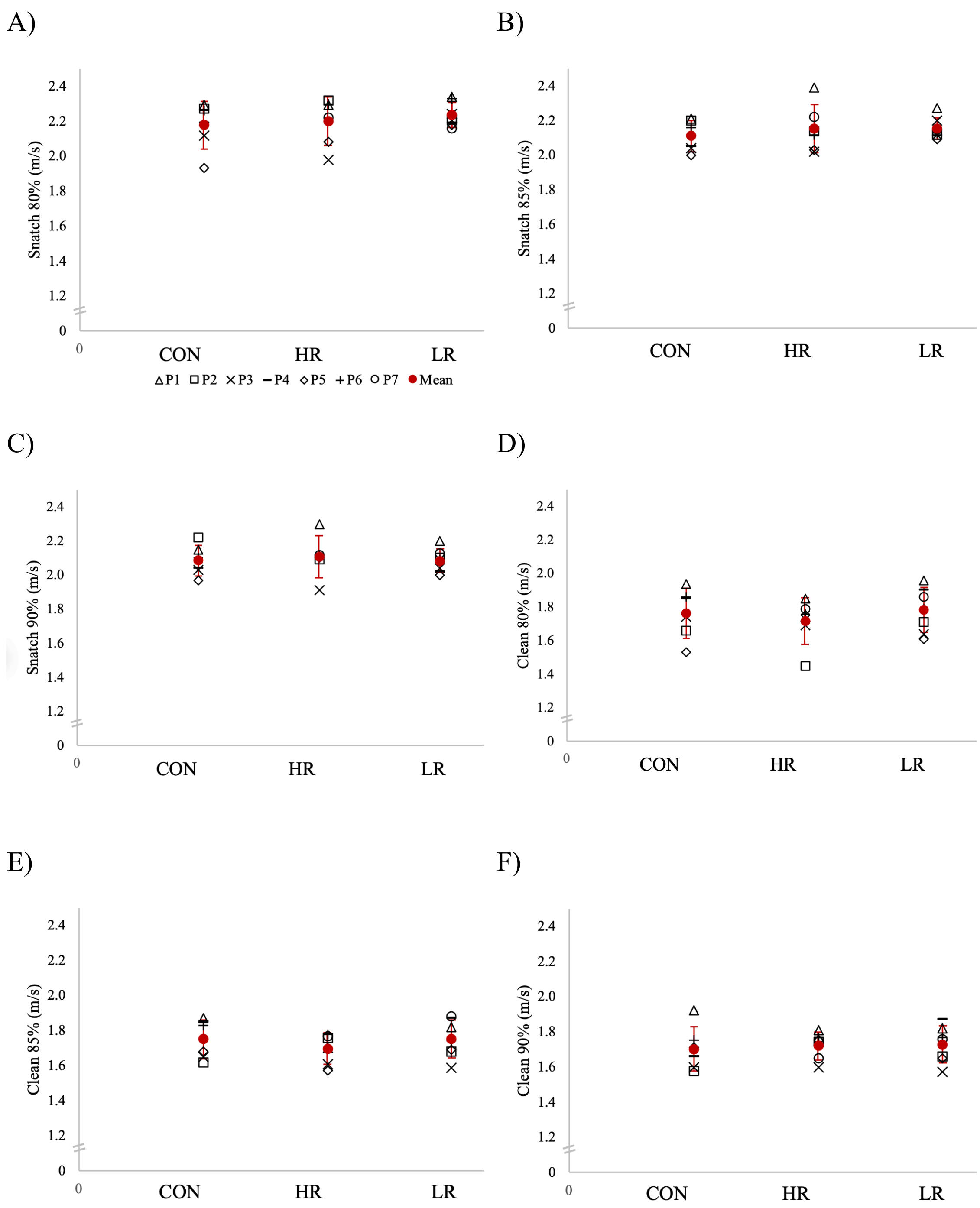

Figure 4.2: Results from video analysis of maximal velocity in snatch and clean. Individual results with mean and SD. n=7. P4 and P7 only have two values in each figure. All other participants have three. All velocity values start at 1.00 A) Results from snatch 80%. B) snatch 85%. C) snatch 90%. D) clean 80%. E) clean 85%. F) clean 90%.

4.3 Pneumatic Leg Press

The change in maximal power (W) between tests were not significant. The mean difference in power from CON to LR was -0.7±5.1% (p=0.41), the mean difference from CON to HR was 0.0±4.0% (p=0.66), and the mean difference from HR to LR was -1.7±3.3. (p=1.00). In maximal force (N) there was a significant difference from CON to HR with -2.5±1.9% (p=0.03*). The mean difference from CON to LR was -1.1±3.6% (p=0.10), and the mean difference from HR to LR was -1.9±2.8% (p=0.41). The change in maximal velocity (m/s) was not significant. The mean difference from CON to LR was -1.8±4.5% (p=0.19), the mean difference from CON to HR was 1.3±1.6% (p=0.32) and the mean difference from HR to LR was 2.0±3.9% (p=0.10).

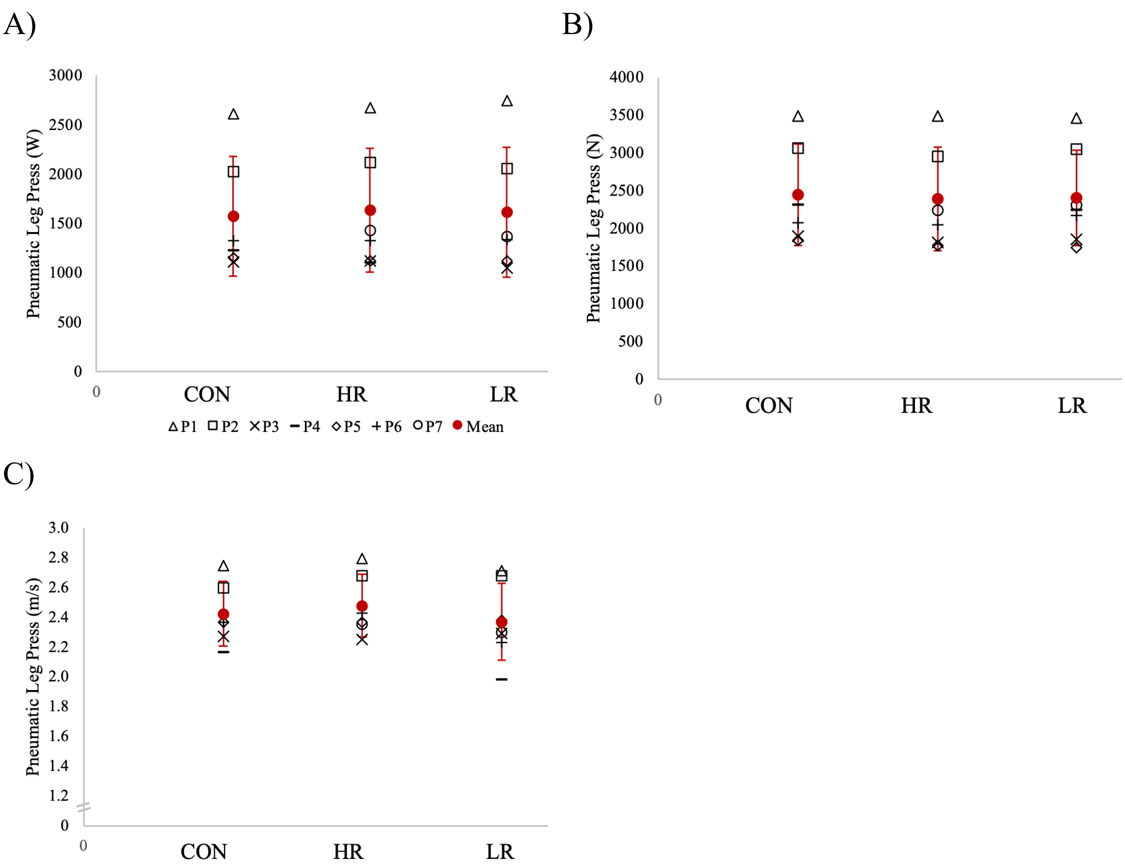

*Figure 4.3: Results from the pneumatic leg press. Individual results with mean and SD. n=7. P4 and P7 only have two values in each figure. All other participants have three. All velocity values start at 1.00. **A)** Power values (w) B) Force values (N) **C)** Velocity values (m/s)*

4.4 Vertical Jumps

The mean difference in SJ from CON to LR was 2.4±5.8% (p=0.41), the mean difference from CON to HR was -4.7±12.9% (p=0.67), and the mean difference between HR and LR was significant with 14.1±16.1% (p=0.01*). S6 and S7 had a large increase in jump height from HR to LR. Five of seven participants had their highest SJ after LR, no subjects had the highest SJ after HR. Looking at maximal power the mean difference between LR and CON was -0.9± 5.1% (p=1.00), the mean difference between HR and CON was -3.1±5.4% (p=0.67), and the mean difference between HR and LR was 5.2±7.4% (p=0.10). In CMJ there was no significant values. The mean difference from CON to LR was 0.8±2.6% (p=1.00), the mean difference from CON to HR was -1.3±5.4% (p=0.66), and the mean difference between HR and LR was significant with 4.0±5.0% (p=0.41). Looking at maximal power the mean difference between LR and CON was 0.1±2.2% (p=0.41), the mean difference between HR and CON was -0.8±3.6% (p=0.66), and the mean difference between HR and LR was 1.9±4.1% (p=0.41).

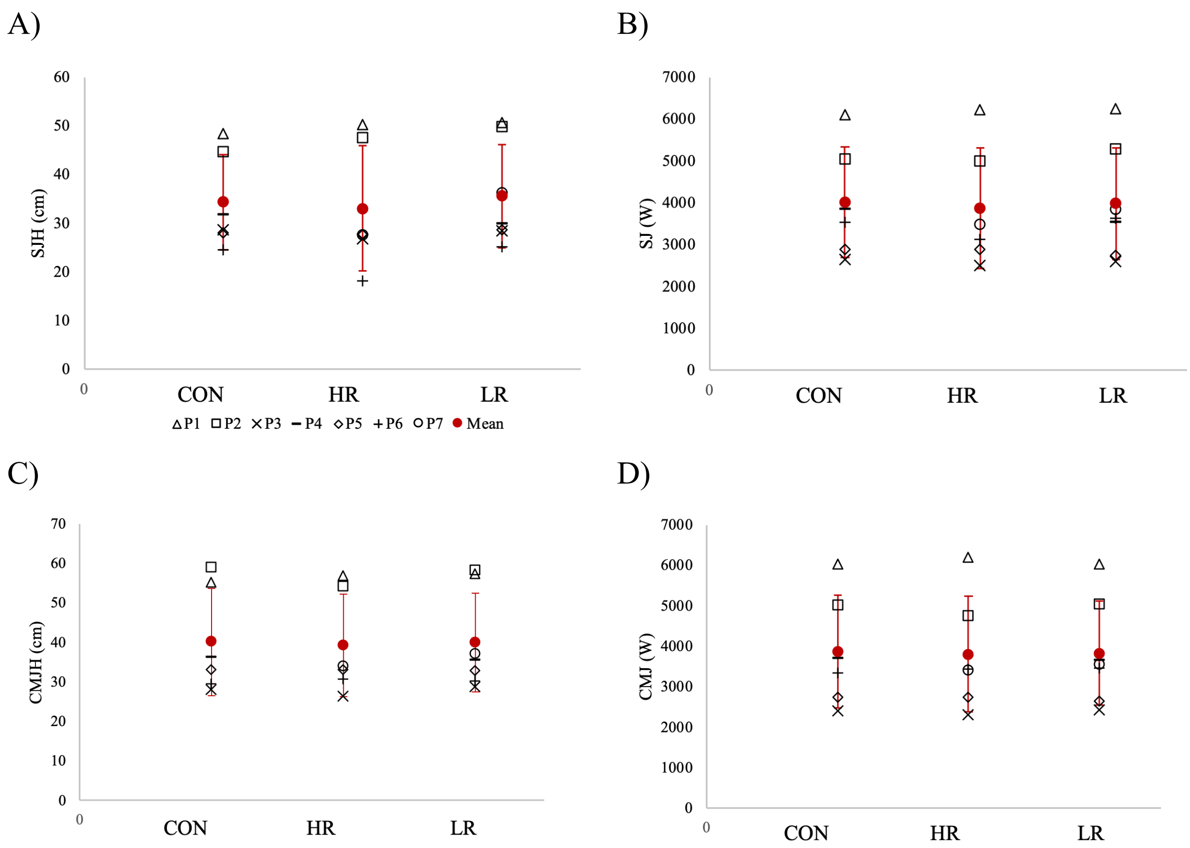

Figure 4.4: Results in vertical jumps. Individual results with mean and SD. n=7. P4 and P7 only have two values in each figure. All other participants have three. A) Squat jump height (cm) B) Peak power in squat jump (W) C) Counter movement jump height (cm) D) Peak power in counter movement jump (W)

4.5 Performance Index

Based on the performance index LR is the condition with the most best test results. There are no significant differences for the generic (p=0.15) tests and the weightlifting (p=0.79) tests (Table 4.5). However, there is a tendency towards a better effect after LR regarding the generic tests.

Table 4.5: Performance index. All test is ranked from 1-3 making the lowest score, the best score.

A)

Test	CON	HR	LR
Pneumatic LP (W)	12	9	9
Pneumatic LP (F)	6	13	11
Pneumatic LP (m/s)	11	8	11
SJH	11	13	6
SJW	10	12	8
CMJH	10,5	10,5	9
CMJW	11	11	8
Sum	71,5	76,5	62

B)

Test	CON	HR	LR
snatch 80	12,5	10,5	7
snatch 85	11	10	9
snatch 90	11	9	10
Clean 80	9	12	9
Clean 85	8	11	11
Clean 90	10,5	8	11.5
Sum	62	60,5	57,5

5. Discussion

5.1 Main Findings

The purpose of this study was to investigate if a light/moderate priming session, a heavy priming session and a rest day could affect the performance differently 24 hours after the priming session in maximal velocity in snatch and clean, jump height and F-v relationship. High (90% of 1RM) and light/moderate (20%/60% of 1RM) resistances (HR and LR, respectively) were applied in two separate sessions and compared to a rest day (CON). There was a significant difference between HR and LR for SJH ($p = 0.01$). And a significant difference between HR and CON in force from the pneumatic leg press ($p=0.03$). No significant differences were found between the different conditions in weightlifting tests. In generic tests no significant differences was found for power and velocity in the pneumatic leg press and CMJW, SJW and CMJH in the vertical jump tests.

5.2 Performance Index

When tests were merely ranked across conditions, LR seemed more favorable compared to HR and CON for generic tests: CMJH, SJH and pneumatic leg press. However, this was not reflected in the weightlifting tests. There were no significant findings for the generic ($p=0.15$) or weightlifting ($p=0.79$) tests from the performance index. There was however a tendency towards LR being the best test regarding generic tests. This tendency was not seen in the weightlifting tests and therefore it is not yet clear if a LR session could enhance weightlifting performance. HR got the highest score in performance index calculated from the generic tests. The high score is indicating that HR did not cause a potentiation in most athletes. In the weightlifting tests CON got the highest score, and LR got the lowest results in both generic tests and weightlifting tests. However, these differences could probably be due to random variations and should not be considered valid results.

5.3 Test Results

5.3.1 Weightlifting Tests

The results from the maximal velocity in snatch and clean was not significant. After LR the participants got the highest mean velocity in 80% snatch, while the participants got the lowest mean velocity in 90% snatch. The highest mean velocity at 90% snatch occurred after HR. Obtaining a high velocity at 90% would probably be considered more important than obtaining a high velocity at 80%. However, there was no significant differences in maximal velocity between the different conditions. In clean the highest mean velocity for the participants occurred after LR on all percentages. However, there is not a lot of researchers who have investigated the clean and jerk. And it's not sure how important the maximal velocity is for the clean regarding performance. A lower maximal velocity in clean compared to snatch is seen in earlier studies (Akkus, 2012; Chiu et al., 2010; Garhammer, 1991; Gourgoulis et al., 2000), as well as in this study. The lower velocity would probably be due to a lower pull in clean compared to snatch.

Only one study known to the author have used snatch and C&J as testing-methods in resistance priming studies (Fry et al., 1995). And no researchers have measured velocity in snatch and clean after a priming session. The reason for not using maximal attempts in this study is to reduce the injury risk for the participants. And because technical errors during lifts possibly could lead to a misinterpretation of the actual effects. Also, maximal snatch lifts before the C&J could possibly make testing more fatiguing. Only analyzing one or the other lift (snatch or clean) could possibly have made it easier to measure both maximal velocity and maximal lift without having to take into consideration the possibility of fatigue prior to the next test. However, during competitions the snatch and C&J is always performed consecutively.

Our participants performed about the same maximal velocities as previously researched athletes (Akkus, 2012; Chiu et al., 2010; Garhammer, 1991; Gourgoulis et al., 2000). During submaximal attempts (70% of 1RM) the velocity can exceed 3m/s in power snatch (Winchester, Porter, & McBride, 2009). No lifter exceeded 3m/s in this study during the measured percentages (80%, 85% and 90% of 1RM). Our participants ranged between velocities of 1.91m/s and 2.30 m/s in 90% snatch. Akkus et al. (2012) Found a mean vertical velocity in the second pull to be 1.68±0.14m/s in female lifters during world weightlifting championship in 2010. Chiu et al. 2010 found the vertical velocity for the worse group, middle and best group were respectively 1.99±0.11m/s, 1.88±0.10m/s and 1.96±0.14m/s on female weightlifters in Taiwanese competitions. And Garhammer et al. (1991) found the maximal velocity to range between 1.94m/s and 2.28m/s from winners in each weight category. Researchers have found the maximal velocities in clean to range between 0.88 to 1.73m/s (Garhammer, 1985, 1991). In this study the maximal velocity at 90% clean ranged between 1.57 and 1.92m/s. All velocities from the aforementioned studies are obtained from female lifters. The velocities are also calculated from the highest successful lift. It is therefore reasonable that lifts at 90% in this study attain a higher barbell velocity than studies using maximal lifts.

In a study by Harbili (2012) the women had a significantly higher mean maximal velocity compared to male weightlifters. Unlike participants in this study where male lifters performed the highest maximal velocities. However, this is probably due to factors like performance level and height (Sato et al., 2012). In the study by Harbili (2012) both female and male lifters were in the 69kg category, which may explain the contradicting results. The maximal velocity of the barbell doesn't necessary reflect the best lifter (Chiu et al., 2010). Weightlifters with a less efficient technique will probably have a higher pull and therefore maybe reach a higher velocity than weightlifters with a more efficient technique. However, some researchers have found maximal vertical velocity and acceleration to be significantly greater in high level athletes (Liu et al., 2018). Chiu et al. (2010), found that the mean maximal velocity was higher in the "worse" group. However, in this study the "worse" lifters were ~10cm taller than the "elite" lifters. Shorter lifters does not need the same vertical barbell displacement as taller lifters, because of the lower catch, and thus smaller lifters do not require the same barbell velocity as taller lifters (Sato et al., 2012). It is therefore not appropriate to compare velocities between different lifters with different heights regarding maximal vertical velocity. However, better lifters have been found to be able to accelerate more throughout the movement instead of deaccelerating between the first and second pull (Isaka, Okada, & Funato, 1996). Acceleration throughout the movement will therefore possibly be a better measurement when comparing lifters against each other.

5.3.1 Pneumatic Leg Press

The pneumatic leg press was probably the most standardized and reliable testing method in this study. In the results from the pneumatic leg press, there was a significant difference in force between CON and HR. Four of five participants performed the best absolute force production after CON. And based on these results it seems like a rest day could enhance performance in maximal force in pneumatic leg press, but also, that a high resistance session could cause fatigue in the force production compared to a rest day. However, looking at maximal velocity, no participants (n=5) performed the best result after CON, which could be contradicting regarding evidence that velocity loss is an indicator of fatigue (Sanchez-Medina & Gonzalez-Badillo, 2011). And it would be expected that the participants would have a higher amount of fatigue after a priming session compared to rest. Therefore, other mechanisms like increased mechanical stiffness could possibly be the reason for the higher velocities measured after priming sessions compared to CON. The different responses of force, velocity and power in the same test in the pneumatic leg press could indicate that different priming sessions affect different abilities of the muscular system.

Because of the large jumps in resistance for each attempt the maximal strength each day is not accurate. The jump from the ninth to tenth repetition was usually around ~20-30kg depending on the 1RM in the pneumatic leg press. However, it is not necessarily the maximal velocity and maximal force who is most important for weightlifting performance, but rather the ability to obtain high velocities at high forces. It is possible for different athletes to achieve the same power with different contribution from force and velocity (Samozino et al., 2012). Information about how different priming sessions affect force and velocity differently could therefore be valuable for athletes regarding enhancing one or the other ability before a competition.

5.3.3 Vertical Jumps

Four of five participants jumped higher in SJ 24 hours after LR. And there was a significant difference between LR and HR in SJH. However, fatigued muscles after HR could also have contributed to the significant difference since no significant difference was found between LR and CON. No significant differences were found in the CMJ.

However, both SJ and CMJ have been strongly correlated with weightlifting performance and have therefore been used to monitor performance in weightlifting (Travis, Goodin, Beckham, & Bazyler, 2018).

Squat jump and CMJ reflect different muscular abilities. And an improvement in CMJ are more affected by an increased ability of the neuromuscular system to utilize the stretch shortening cycle (Komi, 1992). Most studies have used the CMJ as a performance test after a priming session (Cook et al., 2014; Saez Saez de Villarreal et al., 2007; Tsoukos et al., 2018). And a potentiation has also occurred in these studies. The reason why this potentiation is not seen in this study could possibly be because all participants performed the SJ before the CMJ and perhaps suffered some level of fatigue before the CMJ. Also, because of invalid attempts in SJ some of the participants performed more than three attempts. This could have affected the amount of fatigue. Other studies have found a small decline in CMJ performance (Ekstrand et al., 2013; Gonzalez-Badillo et al., 2016; Mason et al., 2017). However, the reason for this small decline could be due to the shorter time of recovery (1.75-6 hours) in these studies in combination with a higher number of repetitions and a high resistance (~80-85%).

In vertical jump a goal is to accelerate as much as possible of the energy in the vertical direction, similar to weightlifting. However, even though LR showed a significantly higher SJH than HR. No such differences were found in weightlifting tests. Also, the highest mean velocity during 90% snatch was obtained after HR where three of five participants performed the highest velocity at 90% snatch after HR. It could therefore be more valuable to look at loaded vertical jumps compared to zero-loaded jumps considering the importance of high force productions in weightlifting.

5.3.4 Vmaxpro

There occurred some problems regarding Vmaxpro, and this makes this tool hard to use in scientific studies. The video is not always recorded, it´s therefore hard to know what part of the lift different graphs belongs to. At some occasions the Vmaxpro did not record at all, and therefore there are missing values. Even though the Vmaxpro is not optimal for scientific studies, it may add valuable information to lifters daily training (more information from the Vmaxpro in attachment III).

5.4 Priming Sessions

There seems to be some consensus between researchers on which priming sessions who enhance subsequent muscular performance most. However, the conditions from different studies are still quite different. There are no specific recommendations in exercises, volume and resistance regarding when the delayed potentiation occurs. Regarding priming sessions, the goal was to have two different training sessions representing the different findings in the current scientific literature. However, these sessions were probably too different as LR was a bit too light, and HR was a bit too heavy or more likely, had a too high volume.

The different conditions were quite similar as priming sessions used in other studies. In the study by Raastad et al (2000), intensities of 70 and 100% was used. These percentages were calculated from 3RM and the percentages in this study was calculated from 60% and 90% of 1RM. Raastad et al. (2000) found a potentiation already a few hours after the 70% strength protocol, this potentiation lasted at least 33 hours. After the 100% protocol the potentiation did not occur until 33 hours post priming session. This could indicate that there will be a small potentiation after a priming session. But the resistance and probably also the total volume of the priming session determines the time length of fatigued muscles before a potentiation occurs. However, there have not been many researchers who have tested the participants more than on two occasions after a priming session, and it´s therefore difficult to say anything about the time course of the fatigue and delayed potentiation.

The intention for HR was to be a low volume session. However, compared to other high resistance sessions, the total volume was probably too high because of the amount of repetitions the athletes needed before the heavier lifts. In the loaded CMJ, 20% of 1RM squat was used. Based on the current research, ballistic priming session under 30% of 1RM cannot induce the delayed potentiation. However, up to 60% of 1RM was also used in the same session for power snatch and power clean + jerk. A higher load in the loaded CMJ could probably still have been used without risking fatigue. Based on the results it seems like HR induced fatigue in some of the participants. The high resistance priming session was also the session with the worse score in the performance index and

HR was also the session who gave significantly poorer results than LR in SJH and CON in pneumatic leg press force.

Because the clean was analyzed and not the jerk, it could be imagined that some of the participants with a better clean than jerk may have underestimated percentages in clean as the 1RM in C&J were used. The actual percentage, and the total stress applied on the muscles may also have been influenced by the technique of the participants. It could be imagined that a participant with a very effective technique will be more fatigued from a 90% snatch or clean and jerk than a person with less effective technique.

5.5 Possible Mechanisms for the Potentiation

The significant findings could potentially be explained by an increased mechanical stiffness (Tsoukos et al., 2018). The lack of improvement in CMJ could be due to a reduced capacity of the stretch shortening cycle (Komi, 1992). However, the possible reduced capacity was most likely from the SJ preformed right before the CMJ rather than the priming session 24 hours earlier. Since no biological tests was taken it´s not possible to say anything about the hormone status in the participants in this study. Even though increased levels of testosterone after a morning session have shown to improve performance in the afternoon (Cook et al., 2014) no significant changes in testosterone, cortisol and sex hormone binding globulin is found 24 and 48 hours after a weight session (McCaulley et al., 2009). It is therefore not likely that hormones could be a reason for the significant findings in this study. However, in the study by McCaulley et al. (2009) there was a trend towards higher levels of testosterone and testosterone/cortisol ratio 24 hours after a hypotrophy session. Even though testosterone could increase to some level after a hypotrophy session, the amount of repetitions would probably be too high and thus possibly cause fatigue

5.6 Limitations

Participants were encouraged to repeat the same training routines every week. However, this was not controlled any further. Neither was fluid intake (Judelson et al., 2007) food intake (Leveritt & Abernethy, 1999) or sleep quality (Reilly & Piercy, 1994). These factors could have affected the day-to-day fluctuations in strength. During testing it was not possible to do weightlifting tests in the laboratory. This is because weightlifters are dependent on dropping the barbell to the floor after a lift to avoid injury. And no weightlifting platform was available in the laboratory. Therefore, all tests were performed in a gym open for students. The number of people present in the gym during testing varied from day to day. A larger and more homogeneous group, and also fewer tests to avoid fatigue during testing could have made the results less splayed.

5.7 Summary and Conclusions

This study is showing a significantly higher SJH 24 hours after LR compared to HR. And a significantly higher force after a CON compared to a HR. These significant differences can have been reinforced by a possible fatigue after HR. There was a tendency towards LR being the favorable priming session for the generic tests. However, there was no such tendencies towards weightlifting tests. Through scientific investigations it exists evidence that priming sessions can enhance subsequent neuromuscular performance. However, recommendations for specific sports is missing. Based on previous research it seems to be a consensus that both heavy low volume workouts and ballistic low/moderate sessions could enhance performance after a priming session.

To answer the scientific questions:

1) There was a significant lower force in the F-v relationship after HR compared to CON. But no significant differences in power or maximal velocity from the F-v relationship. There was not found any significant differences between different priming sessions and rest on maximal velocity in snatch and clean or vertical jump height.

2) There was a significant higher SJH after LR compared to HR. But no significant differences were found in CMJH. There was not found any significant differences between HR and LR on maximal velocity in snatch and clean or the F-v relationship.

In this study there is not enough participants to give recommendations for weightlifting athletes. The few significant findings could be due to the few subjects studied and the variation both in sex and performance level. Therefore, more research on a larger and more homogeneous group is needed.

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Table Overview

Table 2.1.4: *The six phases of the snatch pull. Determined by the change of direction of the knee angles and the height of the barbell (Baumann et al., 1988; Gourgoulis et al., 2000; Harbili & Alptekin, 2014).*

Table 2.3: *Overview of different studies of effects of a priming session. RSI = reactive strength index, MIF = maximal isometric force, RFD = rate of force development, CMJ = counter movement jump, SJ = squat jumps. VJ = vertical jumps. ↑ = improved performance ↓ = reduced performance*

Table 2.4: *Overview of mechanical factors influencing the F-v relationship (Cormie et al., 2011; Samozino et al., 2012).*

Table 3.2: *Participant characteristics. mean±SD (n=7). Sinclair: n=6 (minus one participant without any competitions yet)*

Table 3.3: *Showing low/moderate and high resistance priming sessions. Rep + rep = clean + jerk. # = percentage of 1RM squat. Power snatch and power clean is calculated from 1RM snatch and clean.*

Table 4.1: *Results from all tests. Mean±SD. *significant difference from HR (p=0.05)*

Table 4.5: *Performance index. All test is ranked from 1-3 making the lowest score, the best score.*

Figure Overview

Figure 3.1: *Overview of the testing period. On the day of priming session (PS) or rest, participants were informed by attendance of whenever they were going to perform a low/moderate resistance session (LR), high resistance session (HR) or rest day (CON). Twenty-four hours post condition a test day to measure performance in generic and weightlifting test were completed.*

Figure 3.4.2: *Showing the setup for recording snatch and C&J. This photo is used in consent with the test person.*

Figure 4.2: *Results from video analysis of maximal velocity in snatch and clean. Individual results with mean and SD. n=7. P4 and P7 only have two values in each figure. All other participants have three. All velocity values start at 1.00 A) Results from snatch 80%. B) snatch 85%. C) snatch 90%. D) clean 80%. E) clean 85%. F) clean 90%.*

Figure 4.3: *Results from the pneumatic leg press. Individual results with mean and SD. n=7. P4 and P7 only have two values in each figure. All other participants have three. All velocity values start at 1.00. A) Power values (w) B) Force values (N) C) Velocity values (m/s)*

Figure 4.4: *Results in vertical jumps. Individual results with mean and SD. n=7. P4 and P7 only have two values in each figure. All other participants have three. A) Squat jump height (cm) B) Peak power in squat jump (W) C) Counter movement jump height (cm) D) Peak power in counter movement jump (W)*

Attachments:

Attachment I: Written Consent:

Vil du delta i forskningsprosjektet

«Sammenlikning av forskjellige styrketreningsøkter dagen før en konkurranse i vektløfting»?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke om ulike styrketreningsøkter dagen før en konkurranse i vektløfting vil påvirke vektløfterens prestasjon 24 timer etterpå. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Det er observert ulike rutiner hos vektløftere dagen før en konkurranse. Disse rutinene består av spesifikke treningsøkter eller hviledager. Tidligere studier har observert et vindu etter en styrketreningsøkt hvor man kan oppleve en bedret prestasjon 6 til 72 timer etter treningsøkten. Vi ønsker derfor å undersøke om dette også kan være relevant for vektløftere. I denne studien vil vi undersøke om det er en forskjell i prestasjon etter to ulike styrketreningsøkter som utføres 24 timer før en test.

Dette forskningsprosjektet er en masteroppgave som skal gjennomføres på Norges idrettshøgskole i 2019/20. Resultatene fra denne studien vil kunne gi informasjon om hvordan vektløftere responderer på ulike treningsrutiner dagen før en konkurranse.

Vi søker til denne studien vektløftere på høyt nivå. Om du har lest dette informasjonsskrivet og ønsker å delta som forsøksperson ber vi deg skrive under og returnere den siste siden til oss. Du kan når som helst trekke deg fra studien uten å oppgi grunn.

Hvem er ansvarlig for forskningsprosjektet?
Seksjon for fysisk prestasjonsevne ved Norges idrettshøgskole er ansvarlig for prosjektet.

Prosjektansvarlig er Live S. Luteberget, og Emma Hald er vil gjennomføre datainnsamling i dette prosjektet.

Hvorfor får du spørsmål om å delta?
Du blir kontaktet om deltagelse i prosjektet fordi du er en aktiv vektløfter på høyt nivå. Det vil si at du har fått pallplassering i nasjonalt mesterskap innenfor de tre siste årene.

Informasjonen om deg er hentet inn fra offentlig tilgjengelige resultatlister fra nasjonale mesterskap. Kontaktinformasjon er hentet fra offentlige tilgjengelige opplysninger, eller gjennom ditt særforbund.

Hva innebærer det for deg å delta?
Dette prosjektet innebærer syv oppmøter på Norges idrettshøgskole, hvor du skal delta på én tilvenningsøkt, tre testdager samt gjennomføre to treningsøkter og én hviledag. Treningsøkten skal utføres 24 timer før hver testdag, og vi ønsker at hver testdag er på samme ukedag og tidspunkt i de tre ukene testingen tar. Du vil ha mulighet til å gjennomføre eget treningsprogram de resterende dagene, men vi ønsker at dette skal være likt fra uke til uke.

Treningene vil bestå av øvelser som er kjente for vektløftere, inkludert rykk, støt og knebøy. Hver treningsøkt vil ta i underkant av en time å gjennomføre. På testdagene vil vi teste hopphøyde, kraft-hastighetsprofil i beinpress og hastighet på stangen i rykk og støt på ulike belastninger. Testdagen vil vare i omtrent 1.5 timer.

Mulige ulemper med deltakelsen i denne studien er at du må sette av tid til testing og trening. Gjennomføring av fysiske tester og trening innebærer alltid en viss risiko for skader, men det er ingen grunn til å anta at skaderisikoen er høyere ved deltakelsen i denne studien enn i egen trening.

Det er frivillig å delta

Der er frivillig å delta i prosjektet Hvis du velger å delta, undertegner du samtykkeerklæringen på siste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Dersom du trekker deg fra prosjektet, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskapelige publikasjoner. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Dersom du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med prosjektansvarlig Live S. Luteberget (livesl@nih.no / 40043516), vårt personvernombud Karine Justad (personvernombud@nih.no), eller NSD – norsk senter for forskningsdata AS (personverntjenester@nsd.no / 55582117).

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert.

Navnet ditt er det eneste direkte personidentifiserende opplysning som vil registreres. Navnet ditt vil lagres separat fra dataene, og dermed er det kun en kode som knytter deg til opplysninger gjennom en navneliste. Dette betyr at informasjonen er avidentifisert. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten og som kan finne tilbake til deg. Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Prosjektet skal etter planen avsluttes 01.06.20. Vi er pliktet til å oppbevare data og separat navneliste i 5 år etter sluttdato for etterprøvbarhet og kontroll av resultatene. Etter dette, altså 01.06.25, vil all data i prosjektet slettes.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:
- innsyn i hvilke personopplysninger som er registrert om deg,
- å få rettet personopplysninger om deg,
- få slettet personopplysninger om deg,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Norges idrettshøgskole har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:
- Norges idrettshøgskole ved prosjektansvarlig Live S. Luteberget, på e-post: livesl@nih.no eller telefon: 40043516, eller masterstudent Emma Hald på epost: emma.margrethe@hotmail.com, eller telefon: 91551987
- Vårt personvernombud: Karine Justad (epost: personvernombud@nih.no)
- NSD – Norsk senter for forskningsdata AS, på epost (personverntjenester@nsd.no) eller telefon: 55 58 21 17.

Med vennlig hilsen

Live S. Luteberget	Emma Hald
Prosjektansvarlig	*Masterstudent*
(Forsker/veileder)	

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet ***"Sammenlikning av forskjellige styrketreningsøkter dagen før en konkurranse i vektløfting"***, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i prosjektet som er beskrevet ovenfor
- ☐ at mine opplysninger behandles frem til prosjektet er avsluttet 01.06.20, og at dataene kan lagres frem til 01.06.2025 for etterprøvbarhet og kontroll av resultatene

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(Signert av prosjektdeltaker, dato)

Attachment II: Questionnaire:

Spørreskjema

FP nummer:

Alder:

Hvor lenge har du drevet med vektløfting?

Har du deltatt på konkurranser innenfor vektløfting?

Har du deltatt på internasjonale stevner?

Hva er din 1RM i rykk?

Hva er din 1RM i støt?

Hva er din 1RM i knebøy?

Beste Sinclair score:

Attachment III: Vmaxpro

Comparison of velocity from the Vmaxpro and traditional data analysis

Introduction

Analyzing a lift used to be a time-consuming process where athletes and coaches had to choose one lift for analyzation. Researchers usually spent one week before the digitization of the biomechanics were ready (Reiser, 1996). Today a little accelerometer called Vmaxpro (vmaxpro.de) does the same job in seconds. The Vmaxpro is three-axial accelerometer which can be placed on the barbell with the help of a magnet and strap. It can be synchronized with video recording and measures acceleration in three axes together with sensor orientation in space (vmaxpro.de). The Vmaxpro is a new device (launched 2016) and could possibly help scientists, athletes and coaches to easier analyse lifts and other sport related movements. The purpose of this study was to figure out if the Vmaxpro could produce valid results in comparison with the traditional video analysis. And if the Vmaxpro was a good tool in science and training. A research question was therefore defined: a) What is the correlation between Vmaxpro and a traditional video-analysis, and b) how is Vmaxpro as a tool in training and science.

Method

In this project the Vmaxpro was used together with a traditional analysis of the maximal velocity during snatch and clean. The sensor was placed on the bar with a magnet and a safety strap. The sensor sends information to an accompanying app on an iPad who are recording the movements. From this app information about the lifts is available immediately after the lift. The information includes barbell trajectory, acceleration and maximal velocity of the barbell. The traditional analysis included video recordings (240Hz) with an iPhone 8 camera in the sagittal plane. To calibrate the two-dimensional area, two calibration sticks of one meter was placed on the platform. To determine the two-dimensional kinematic data from the barbell, an orange mark with a reflective marker was placed on the end of the barbell to track barbell path and calculate barbell velocity. The flash on the iPhone was used to better observe the reflective marker. The snatch and clean was analyzed. Peak velocity was calculated from the time and position of the barbell using Tracker 5.1 (Tracker version 5.1.2, Douglas Brown, Open Source Physics, USA). In the analyses the video was cut from the beginning of the first pull (lift off) to the end of the top pull right before catching the barbell. In the analysis the reflective marker was tracked, and the frame was calibrated with measuring both calibration stick. From this information tracker 5.1 could calculate velocity. All data was copied to excel where the peak velocity and maximal velocity was found and calculated. First the peak velocity was found. Subsequently the maximal velocity was defined as the mean between the peak velocity and the two upper and lower values. Correlation analysis with a 95% confidence interval was used to see if there was a relationship between results from Vmaxpro and traditional analysis.

Results

There was an almost perfect correlation between Vmaxpro and the traditional analysis (r=0.91) (Hopkins, 2000). The mean difference between Vmaxpro and the traditional analysis was 0.10±0.12m/s.

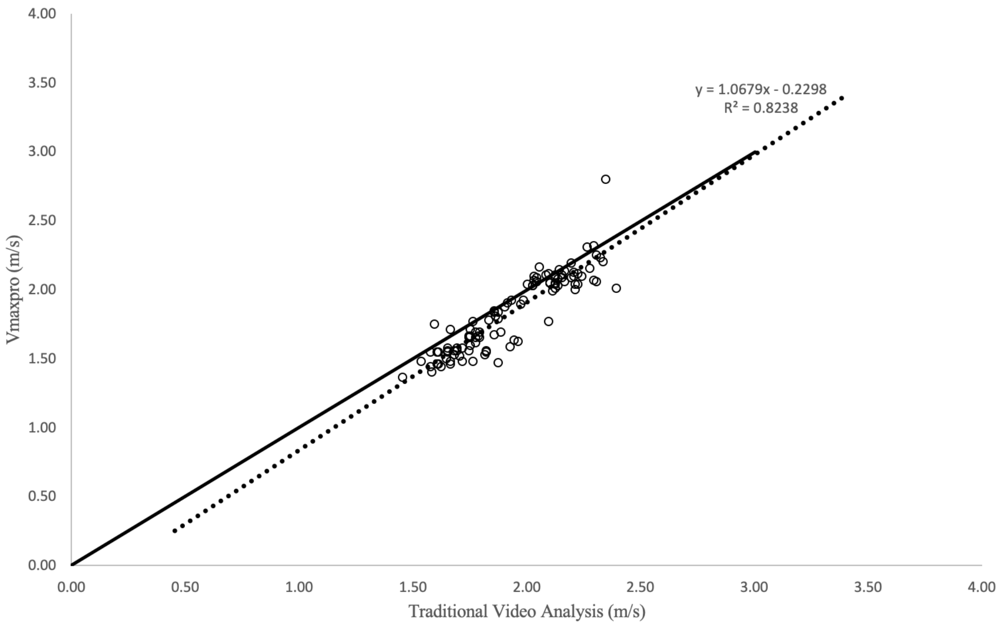

Figure 1: XY scatter plot showing correlations between the traditional video-analysis and the Vmaxpro (95% CI). Each point is connected by results obtained from the same lift, calculated from a traditional video-analysis and the Vmaxpro. The dotted line is representing the linear trend line (r=0.91). The solid line is the line of equality where y=x.

Discussion

There is a strong correlation between Vmaxpro and the traditional analysis. Video-analysis is a widely used method for measuring velocity during Olympic lifts (Akkus, 2012; Chiu et al., 2010; Garhammer, 1991; Gourgoulis et al., 2000). This means that a good correlation between Vmaxpro and the traditional video analysis could indicate that the Vmaxpro gather good and valid information. However, comparing the results from the Vmaxpro with a gold standard motion analysis system in the future could give an even better validation of the accelerometer.

There occurred some problems regarding Vmaxpro, and this makes this tool hard to use in scientific studies. The video is not always recorded and it´s therefore difficult to know what part of the lift different graphs belongs to. There Vmaxpro did not always measure movements, and it is therefore missing values. Even though the Vmaxpro is not optimal for scientific studies, it may add valuable information to lifters daily training.

Conclusion

There is a strong relationship between Vmaxpro and a traditional analysis (r=0.91). However, it is difficult to use the Vmaxpro in scientific studies because of unknown errors during measurements. In training Vmaxpro could be a valuable tool for athletes and coaches.

References

Reiser, R.F., Smith, S.L., Rattan, R. (1996). Science and Technology to Enhance Weightlifting performance: The Olympic Program. *Strength and Conditioning Journal, 18(4), 43-51.*

Vmaxpro.de Performance diagnostics should be simple – with Vmaxpro Science it is. Retrieved from https://vmaxpro.de/vmaxpro-science/