EXERTION/VELOCITY PROFILING AND ASSESSMENT OF ACCURACY OF INTRA-SET RATING OF PERCEIVED EXERTION IN THE FRONT SQUAT AND HEXAGONAL BAR DEADLIFT

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Johnathan Boe Odgers, candidate for the degree of Master of Science in Kinesiology & Health Studies, has presented a thesis titled, *Exertion/Velocity Profiling and Assessment of Accuracy of Intra-Set Rating of Perceived Exertion in the Front Squat and Hexagonal Bar Deadlift*, in an oral examination held on November 4, 2019. The following committee members have found the thesis acceptable in form and content, and that the candidate demonstrated satisfactory knowledge of the subject material.

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Abstract

Autoregulation is defined as a systematic approach of incorporating individualization into a periodized strength training plan to allow progression towards maximal performance. Recent literature in the areas of velocity-based training (VBT) and the use of rating of perceived exertion (RPE), based on repetitions in reserve (RIR), have become integral components of individualizing strength training programs. The primary purposes of this study were: 1) to examine the accuracy of intra-set RPE across multiple sets to volitional fatigue at 80% 1-repetition maximum (1-RM) in the front squat and high-handle hexagonal bar deadlift (HHBD) and, 2) to determine the relationship between average concentric velocity (ACV) and RPE in the front squat and HHBD in trained males and females (defined as those being able to front squat 1.5x their body mass and HHBD 2x their body mass). Participants performed four sets to volitional fatigue for both the front squat and HHBD at 80% 1-RM. During each set, participants verbally indicated when they believed they were at “6” and “9” on the RPE scale. Results showed that an RPE of “9” was significantly more accurate than an RPE of “6” for the front squat (males: 0.09 versus 0.71, p < 0.001; females: 0.19 versus 0.86, p < 0.001) and HHBD (males: 0.25 versus 1.00, p = 0.004; females: 0.21 versus 1.19, p < 0.001). A very strong inverse relationship between ACV and RPE was also found in the front squat (r = -0.98) and the HHBD (r = -1.00). These results may have application for using the RPE scale with a higher degree of accuracy based on ACV for program training progression.

Keywords: RPE, ACV, Autoregulation, Front Squat, Hex Bar Deadlift
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List of Abbreviations

1-RM – 1 repetition maximum
ADP – adenosine diphosphate
AM – anthropometric measurements
ATP – adenosine triphosphate
ATPase – adenosine triphosphatase
BM – body mass
BPM – beats per minute
e1-RM – Estimated 1-Repetition Max
GAS – general adaptation syndrome
GH – growth hormone
HHBD – high-handle hexagonal bar deadlift
HHQ – health history questionnaire
IGF-1 – insulin-like growth factor-1
LPT – linear position transducer
m/s – meters per second
MCV – mean concentric velocity
MVT – minimal velocity threshold
PAQ – physical activity questionnaire
PC – phosphocreatine
PCV – peak concentric velocity
RIR – repetitions in reserve
RPE – rating of perceived exertion
RPEDIFF – RPE difference
SD – Standard Deviation
TP – training protocol
VBT – velocity-based training
1 Introduction

Muscle contraction is influenced by many factors, such as high-energy phosphate metabolism, energy status, neuromuscular activation, pennation angle, muscle fiber morphology, and hormonal regulation (Powers & Howley, 2015; Schoenfeld, 2013; Scott, Stevens & Binder-Macleod, 2001; Tortora & Derrickson, 2008). Traditionally, most strength training programs are designed using a percentage of 1-repetition maximum (1-RM). Unfortunately, percentage of 1-RM has been shown to produce different outcomes in individuals performing repetitions to volitional fatigue (Richens and Cleather, 2014). Therefore, the utilization of velocity-based training (VBT) and rating of perceived exertion (RPE), based on repetitions in reserve (RIR), have become integral components in current strength training program designs.

Autoregulation, a systematic approach of incorporating individualization into a periodized strength training program (Helms, 2017), can be implemented to overcome the shortcomings of using percentage 1-RM for prescribing resistance training intensity. The new RPE scale, a form of autoregulation, is from 1-10 and was first published and validated in the literature by Zourdos et al. (2016b) whereby an RPE of 10 corresponds to 0 RIR, an RPE of 9 corresponds to 1 RIR, an RPE 8 corresponds to 2 RIR, etc. RPE was compared to percentage 1-RM over an 8-week training study for prescribing intensity and the RPE-based loading group had slightly higher increases in strength (Helms et al., 2018).

VBT is also a form of autoregulation where a linear position transducer (LPT) is used to measure the average concentric velocity (ACV) of the barbell in meters per second (m/s). ACV is the main velocity measure examined as it best represents the ability of the athlete to move the load through the entire concentric portion of the exercise (Jidovtseff, Harris, Crielaard & Cronin, 2011). Strong inverse relationships between RPE and velocity have been observed on the squat
(r = -0.87, p < 0.001), bench press (r = -0.79, p < 0.001) and deadlift (r = -0.82, p < 0.001; Helms et al., 2016). The minimum velocity threshold (MVT) is the ACV of the final successful repetition in a repetition-to-volitional fatigue set, or at 1-RM (Jovanović & Flanagan, 2014). MVT’s are exercise specific and have been shown to be the same across 60, 65, 70, and 75% of 1-RM in the squat (Izquierdo et al., 2006). Therefore, velocity can be used to autoregulate load and possibly predict RIR. The front squat and high-handle hexagonal bar deadlift (HHBD) are commonly used movements due to their decreased erector spinae activity and upright torso position when compared to the back squat and conventional deadlift (Stewart & Stewart-Menteth, 2008; Swinton, Stewart, Agouris, Keogh & Lloyd, 2011; Braidot, Brusa, Lestussi & Parera, 2007).

The purpose of this thesis was to examine the relationship between ACV and RPE in the front squat and HHBD and to examine the accuracy of intra-set RPE ratings in trained males and females.

2 Literature Review

2.1 Muscle Biology

2.1.1 High Energy Phosphate Metabolism

During resistance training, the immediate source of energy for muscular contraction comes from the high-energy phosphate compound adenosine triphosphate (ATP; Powers & Howley, 2015). The most rapid method to resynthesize ATP involves the donation of a phosphate group from phosphocreatine (PC) to adenosine diphosphate (ADP) (Powers & Howley, 2015). However, muscle cells only store small amounts of PC, and thus limit the amount of ATP that can be produced. The combination of stored ATP and PC is called the ATP-
PC system, or the “phosphagen system”. This system provides energy for muscular contraction at the onset of high intensity exercise lasting five seconds or less.

2.1.2 Muscle Fiber Morphology

Muscle fibers can be divided into three different types based on their histochemical or biomechanical characteristics: type I, type IIa, and type IIx. Type I fibers (also called slow-oxidative or slow-twitch fibers) contain large numbers of oxidative enzymes, such as mitochondria, surrounded by a high number of capillaries and contain a high concentration of myoglobin (Tortora & Derrickson, 2008). These factors provide type I fibers with a large capacity for aerobic metabolism while being resistant to fatigue. Furthermore, type I fibers contain less actin and myosin per cross-sectional area than type II fibers, resulting in lower maximal shortening speed, specific force production, and maximal power (Powers & Howley, 2015).

Fast-twitch fibers have two subtypes: type IIa and type IIx. Type IIx fibers are rich in glycolytic enzymes, giving them a large anaerobic capacity due to their relatively small number of mitochondria (Tortora & Derrickson, 2008). Type IIx fibers have the highest adenosine triphosphatase (ATPase) activity resulting in the highest contraction velocity max and power output (Powers & Howley, 2015). However, this also makes them very inefficient due to the high energy expenditure per unit of work. Type IIa fibers contain biomechanical and fatigue characteristics between type I and type IIx fibers. When contractile properties of each fiber type are examined, type IIx has the highest maximal shortening velocity, specific force output and power, with type IIa being lower and type I being the lowest (Powers & Howley, 2015).
2.1.3 Pennation Angle

Skeletal muscle fibers within a muscle are arranged in bundles known as fascicles (Powers & Howley, 2015). Within a fascicle, all muscle fibers are arranged parallel to one another. However, the fascicles may form one of five patterns with respect to the tendon: parallel, fusiform, circular, triangular, and pennate (Powers & Howley, 2015). The arrangement of these fascicles will affect muscular strength, power output, and range of motion. During contraction, a muscle shortens 70% of its resting length. The power of a muscle is not dependent on its length, but rather its cross-sectional area (Tortora & Derrickson, 2008). Furthermore, fascicle arrangement presents a compromise between range of motion and power output. Pennate muscles have a large amount of short fiber fascicles distributed over their tendons giving them high power output, but small range of motion (Haff & Triplett, 2015). In contrast, parallel muscles have less fascicles, but cover a greater distance giving them low power output and greater range of motion (Haff & Triplett, 2015).

2.1.4 Neuromuscular Activation

A motor unit is defined as a motor neuron and all the muscle fibers it innervates (Powers & Howley, 2015). The force exerted by a muscle during a voluntary contraction is dependent on the number of motor units recruited and the rate at which action potentials are discharged (rate coding; Enoka & Duchateau, 2017). Resistance trained individuals exhibit higher rates of torque development and explosive force than untrained individuals in the very early phases of contraction (Del Vecchio et al., 2018). These observations are most likely explained by the recruitment of fast-twitch motor units that have large motor units with large muscle fiber diameters in a very short amount of time. Increasing the size of a motor unit and the speed at
which those motor units are recruited will lead to substantial increases in muscular force production and contraction velocity.

2.1.5 Anabolic Hormones

Three primary anabolic hormones have been studied to examine their effect on muscular hypertrophy and adaptation to resistance training: insulin-like growth factor-1 (IGF-1), growth hormone (GH), and testosterone (Schoenfeld, 2010). IGF-1, a peptide hormone, is often referred to as an important anabolic hormone. It is theorized to be upregulated in response to mechanical loading. The promotion of anabolism comes from an increased rate of protein synthesis in differentiated myofibrils. Moreover, IGF-1 stimulates satellite cell activity and their proliferation and differentiation, potentially leading to muscle hypertrophy (Schoenfeld, 2010).

Testosterone is a cholesterol-derived hormone that has substantial effects on muscular hypertrophy and force generating capacity. Furthermore, it has the ability to interact with receptors on neurons to increase the number of neurotransmitters released, regenerate nerves, and increase cell body size (Schoenfeld, 2010). In the presence of mechanical loading, testosterone increases muscle protein synthesis, inhibits muscle protein breakdown, promotes satellite cell replication and activity, and releases GH (Schoenfeld, 2010). Significant correlations between training-induced elevations in testosterone and muscle cross-sectional area have been observed (Ahtiainen, Pakarinen, Kraemer & Häkkinen, 2003).

GH is a polypeptide hormone that possesses both anabolic and catabolic properties. GH acts to repartition fat metabolism toward the mobilization of triglycerides and to stimulate cellular uptake of amino acids into the muscle (Schoenfeld, 2010). Exercise-induced increases in GH have been highly correlated with type I and type II muscle hypertrophy (McCall, Byrnes, Fleck, Dickinson & Kraemer, 1999). Furthermore, GH is also thought to be involved in the
exercise-induced increase in locally expressed IGF-1, facilitating fiber recovery and stimulating a hypertrophic response (Schoenfeld, 2010).

2.2 Autoregulation

Autoregulation is defined as a systematic approach of incorporating individualization into a periodized strength training program (Helms, 2017) for subsequent maximum performance (Mann, Thyfault, Ivey & Sayers, 2010). Autoregulation adjusts specific training variables, such as load or perceived exertion, to meet a planned or strategic goal (Helms, 2017). For the purpose of this thesis, prescribed load will be based on perceived exertion, rather than a percentage of 1-RM. Helms et al., (2018) showed that strength-trained athletes who used RPE as their main training principle increased muscle strength (squat, bench press) to a slightly greater degree compared to those who use percent baseline 1-RM over 8 weeks of training.

2.2.1 Issues in Using Percentage 1-Repetition Max

Percentage 1-RM is a popular variable in strength training program design. However, at higher training intensities (> 60% 1-RM), using baseline percent 1-RM may result in large differences in the number of repetitions performed at a given percentage of 1-RM (Richens and Cleather, 2014). For example, Richens and Cleather (2014) examined differences in leg press muscle performance between endurance athletes and strength trained athletes. Participants performed 3 sets of leg press to volitional fatigue at 70%, 80% and 90% baseline 1-RM. Results showed that the endurance athletes completed significantly more repetitions at 70% and 80% baseline 1-RM. There were no differences between training modalities at 90% baseline 1-RM. Results across different training intensities (i.e. % 1-RM) suggest the utilization of a pre-set training stimuli may not be optimal for strength training progression. Autoregulation may help overcome daily fluctuations in strength.
2.2.2 Individual Rates of Adaptation

Rates of adaptation and recovery can vary (McLester et al., 2003) with genetics (Timmons, 2018), biological age (Lemmer et al., 2000), menstrual cycle phase (Sarwar, Niclos & Rutherford, 1996), and training status (Baker, 2013) all influencing the magnitude of adaptation. Hubal (2005) showed that individuals who performed the same 12-week training program had vastly different adaptations. Some individuals had no increase in strength or hypertrophy, while others increased muscular size by ~ 60% and strength by 250%. The general adaptation syndrome (GAS) states that stress is required for adaptation (Selye, 1950). If the stress applied is too large and exceeds the recovery abilities of an individual, performance will decrease and lead to an acute state of exhaustion (Selye, 1950). Recovery is a multi-factorial process that can be impacted by sleep (Bulbulian et al., 1966), nutrition (Helms et al., 2015), and psychological factors (Stults-Kolehmainen and Sinha, 2014). Bartholomew, Stults-Kolehmainen, Elrod and Todd (2008) found that negative life stress can blunt strength increases from training. The physiological response to training is individual and the utilization of the RPE scale may help attenuate these differences.

2.3 RPE

2.3.1 History of the Rating of Perceived Exertion Scale

The RPE scale was introduced to the literature by Gunnar Borg (1970). His original scale ranged from six to 20 and was correlated to heart rate during aerobic training (60 beats per minute [bpm] corresponded to 6 while 200 bpm corresponded to 20). Twelve years later, Borg (1982) created a simplified version of this original scale which ranged from one to 10. When using the RPE scale for resistance training, anchoring is crucial. Anchoring is the process of
correlating a specific amount of exertion to a number on the RPE scale. If anchoring does not occur, participants will draw on previous experiences that correlated with the same level of exertion to score their RPE. Shimano et al. (2006) had un-anchored participants score RPE’s of 6.1-8.8/10 when they performed 60, 80, and 90% of 1-RM to volitional fatigue in the back squat, bench press and bicep curl. Performing an exercise to volitional fatigue should yield an RPE of 10, thus highlighting the importance of anchoring. The modified RPE scale, based on RIR (RPE-RIR), incorporates anchoring. Trained participants have been shown to have a higher degree of accuracy with the RPE-RIR scale compared to untrained participants (Zourdos et al., 2016b). It has recently been recommended that the RPE-RIR scale should replace the Borg scale when assessing resistance training intensity (Helms, Cronin, Storey & Zourdos, 2016). The RPE-RIR scale allows individuals to manipulate load to achieve a desired intensity specific to that day rather than a percentage of a previous 1-RM test, which may not be representative of their current training status (Helms, Cronin, Storey & Zourdos, 2016).

2.4 Velocity-based training

Linear position transducers (LPT) can accurately measure barbell velocity to create load-velocity profiles for training. The three metrics that are most commonly measured are: 1) Mean Concentric Velocity (MCV), 2) Peak Concentric Velocity (PCV) and, 3) Minimal Velocity Threshold (MVT, Jovanović & Flanagan, 2014). When measuring the velocity of ballistic strength training exercises such as the squat and bench press, Jidovtseff et al. (2011) suggests using MCV over PCV as it is a better representation of the ability of the athlete to move the load through the entire concentric phase of the lift. Training the concentric portion of the lift with maximal effort is believed to increase the adaptations to training regardless of contraction type, load, or absolute/actual movement velocity of the exercise (Behm & Sale, 1993; Cormie,
McGuigan & Newton, 2011; Crewther, Keogh, Cronin & Cook, 2006). Therefore, athletes should train with the intent to move the barbell with the highest effort and movement velocity possible, which are both vital stimuli required to drive adaptation (Cormie et al., 2011).

2.4.1 Linear Position Transducers

Movement velocity, as measured using linear position transducers (LPT), is an isoinertial resistance training variable which can influence resistance-training progression (Izquierdo et al., 2006). LPTs operate with the use of a cord wound on a constant diameter cylinder spool that rotates as the barbell is pulled closer and further from the LPT (Harris, Cronin, Taylor, Jidovtseff & Sheppard, 2010). This spool is attached to the shaft of a rotational sensor (encoder or potentiometer) that produces an electrical signal proportional to the velocity or displacement of the barbell producing the speed in meters per second (m/s; Harris et al., 2010). Furthermore, all data is provided in real time and can be used through an electronic handheld computer device (such as an iPad or tablet) allowing for intraset/intrasession load autoregulation.

2.4.2 Neuromuscular Fatigue

When multiple sets are performed to volitional fatigue, regardless of inter-set rest periods, there is a reduction in total training volume (sets x repetitions x load) performed per session (Richmond & Godard, 2004). Since training volume is a key factor in determining strength adaptations (Klemp et al., 2016), caution should be taken when training to volitional fatigue. For example, Pareja-Blanco et al., (2018) examined the time of recovery from training to volitional fatigue vs. training to a RPE of 5-8. Results showed that training to volitional fatigue delayed recovery 48 hours post-workout and could potentially interrupt subsequent training volume, intensity and frequency.
The onset of neuromuscular fatigue can negatively impact neural signaling pathways and force generation capacity (Häkkinen, 1993), which can be quantified by a decrease in movement velocity as a set progresses and a decrease in the rate of force development (Vøllestad, 1997; Walker, Taipale, Nyman, Kraemer & Häkkinen, 2011). While RPE and ACV having a strong inverse relationship (see section 2.3.3), LPTs can be used to autoregulate training intensity and adjust for neuromuscular fatigue. Furthermore, the use of immediate feedback via LPTs results in increased consistency of movement velocity (Randell, Cronin, Keogh, Gill & Pedersen, 2011a) and greater adaptations compared to those who did not receive immediate feedback (Randell, Cronin, Keogh, Gill & Pedersen, 2011b). Findings across studies support a rationale for not training to volitional fatigue across multiple sets in a resistance training session.

2.4.3 Relationship Between RPE and Velocity

Zourdos et al. (2016b) compared the accuracy of the RPE scale and the ACV of experienced squatters and novice squatters in the back squat. Experienced squatters showed significantly slower velocities and higher RPEs at 90 and 100% 1RM which indicates they were more efficient at high intensities. However, there were no significant differences between groups at 60 and 75% or the first and eighth repetitions at 70% 1RM. Additionally, experienced squatters exhibited a strong inverse relationship between average velocity and RPE at all parentages (r = -0.88).

Helms and colleagues (2017) compared ACV and RPE in the squat, bench press, and deadlift. They found very strong relationships (r = 0.88-0.91) between RPE and percentage 1RM for each lift. ACV showed strong (r = -0.70 to -0.87) and very strong (r = -0.90 to -0.92) inverse relationships between RPE and percentage 1RM on each lift. Likewise, González-Badillo & Sánchez-Medina, (2010) reported a very strong relationship between velocity and load with a R²
value of 0.993 – 0.999. Both studies show a very strong inverse relationship between velocity and intensity (%1RM/load) in resistance trained subjects in multi-joint movements.

2.4.4 Minimum Velocity Thresholds

The MVT of an exercise is defined as the ACV produced on the final successful repetition of a set performed with maximal lifting effort or at 1-RM (Jovanović & Flanagan, 2014). MVT’s are exercise specific. Sánchez-Medina, González-Badillo, Perez & Pallarés (2014) found the MVT of the bench press to be 0.17 m/s and the prone pull to be 0.52 m/s. Furthermore, the MVT appears to be the same during a 1-RM test compared to a sub-maximal repetition-to-volitional fatigue test (Izquierdo et al., 2006). They also found that when subjects performed the squat and bench press to volitional fatigue at intensities of 60, 65, 70, and 75% of 1-RM, MVT was not statistically different.

MVT does seem to vary slightly between athletes, with the strongest athletes having the ability to produce lower MVTs when compared to weaker athletes. Zourdos et al. (2016) showed that experienced squatters had a MVT of 0.24 m/s and novice squatters had a MVT of 0.34 m/s. MVTs appear to be consistent when an athlete gains strength, but not when they lose strength (González-Badillo & Sánchez-Medina, 2010; Sanchez-Medina, Perez & Gonzalez-Badillo, 2010). Furthermore, Banyard, Nosaka, Vernon & Haff (2017) found that PCV, AVC, and mean propulsive velocity (MPV) were all sufficiently reliable at 20, 40, 60, 80, and 90% 1-RM over the course of three different training sessions. Although, at 100% of 1-RM, the only velocity measure that was reliable was PCV. This suggests that the velocity at 1-RM can vary from session to session for an athlete, but the use of autoregulating load may be more appropriate at submaximal intensities. At 1-RM, ACV values (0.24 ± 0.05 m/s) found by Banyard et al. (2017)
were in line with Zourdos et al. (2016b) findings (0.24 ± 0.04 m/s) meaning MVTs may be the same across a trained population.

2.4.5 Exertion – Load Profiling

To date, there is only one study that has the available data to create a comprehensive exertion – load profile for the squat. Izquierdo et al. (2006) had participants perform the back squat to volitional fatigue at 60, 65, 70, and 75% of 1-RM while measuring ACV of every repetition. Furthermore, they also found that the average amount of RIR for the back squat, across all intensities, was extremely similar at nine RIR and three RIR. Within a range of nine to zero RIR, for all intensities, the standard deviation was 0.02 m/s, with a coefficient of variation of three percent to six percent (Izquierdo et al., 2006). This data provides the ability to predict how many RIR an athlete has at any intensity. Additionally, data can be used to autoregulate the load a lifter is using by examining the ACV of their warmups, and working sets, to ensure the appropriate RPE is being performed for that training session.

2.5 Front Squat and Hex Bar Deadlift

The front squat is a variation of the back squat, where the barbell is placed on the anterior deltoids and clavicles, and fully flexing the humerus until it is parallel with the floor (Gullett, Tillman, Gutierrez & Chow, 2009). The HHBD is a variation of the conventional deadlift, where the lifter steps inside of a hexagonal shaped bar and grips with bar with the palms facing the lateral aspect of the fibula (Lockie et al., 2018).

When compared to the back squat, the front squat has decreased knee extensor moments and compressive forces (Gullett et al., 2009). Although these compressive and extensor moments were much lower in the front squat, overall muscle activity was the same between the back squat and front squat (Gullett et al., 2009). The front squat was shown to have a more upright torso
angle in order to balance the line of gravity of the barbell over the mid-foot (Braidot, Brusa, Lestussi & Parera, 2007). Likewise, the HHBD was also shown to have a more erect torso position when compared to the conventional deadlift, and reduced erector spinae activity during the ascent and decent, which lead the authors to conclude that it may be a safer method of lifting (Stewart & Stewart-Menteth, 2008).

Range of motion, peak power, and ACV was compared in the conventional deadlift and the HHBD (Lockie et al., 2018). They found that the trained participants were able to lift significantly more absolute load (15%) in the HHBD compared to the conventional deadlift and the vertical displacement and time to completion was significantly lower in the HHBD resulting in 22% and 25% decreases, respectively (Lockie et al., 2018). Moreover, peak power was 47% higher in the HHBD as well as peak velocity being 22% higher (Lockie et al., 2018). Finally, ACV between the conventional deadlift and HHBD was not significantly different, with ACV scores of 0.30 m/s and 0.32 m/s, respectively (Lockie et al., 2018).

Both the HHBD and front squat have become integral components of elite level strength and conditioning programming. According to Fry, Smith and Schilling (2003), front squats may be a superior alternative to back squats due to their significantly lower knee compressive forces and lumbar stress. Schoenfeld (2010) also stated that the front squat is beneficial for athletes who compete in Olympic weightlifting, or who have a variation of the clean in their programming, due to the carry over to the catch position in a clean. Strength and conditioning programs, especially those who coach team sports such as ice hockey, basketball, and football, utilize the front squat in a majority of their programs as a power exercise. The HHBD is a very popular exercise in the strength and conditioning community due to the decreased erector spinae activity and more erect torso position as well as higher peak power, velocity, and force, leading to the
conclusion that is may be a safer and advantageous alternative to the conventional deadlift (Stewart & Stewart-Menteth, 2008; Swinton, Stewart, Agouris, Keogh & Lloyd, 2011).

2.6 Summary

High-energy phosphate metabolism, energy status, neuromuscular activation, pennation angle, muscle fiber morphology, and hormones all play a significant role in force producing capabilities and speed of muscular contraction (Powers & Howley, 2015; Schoenfeld, 2013; Scott, Stevens & Binder–Macleod, 2001; Tortora & Derrickson, 2008). Due to the large variation in daily readiness, percentage of 1-RM prescribed loading may be inferior as it could misrepresent an individual’s acute performance capability. RPE based on RIR aims to account for these variations through autoregulation to maximize performance and may increase strength more than percentage 1-RM based loading (Helms et al., 2017). VBT, through the measurement of ACV, can be used as a training metric alongside RPE to autoregulate training more effectively. Furthermore, RPE and ACV have a very strong inverse relationship (Zourdos et al., 2016b).

This thesis aimed to measure the relationship between RPE and ACV in the front squat and HHBD. Results obtained in this thesis may potentially be used to autoregulate load to more accurately achieve the desired training intensity for a given session. Intraset RPE accuracy was assessed to further investigate how RPE can be utilized to maximize resistance training performance.

2.7 Research Questions and Hypotheses

1. Is there a significant difference in the accuracy of verbal intra-set RPE callouts of ”6” and “9” in multiple sets in the front squat and HHBD at 80% 1-RM to volitional fatigue?

Hypothesis #1: RPE callouts will be more accurate for “9” vs. “6” in all sets and the average
accuracy will be significantly more accurate at “9” vs “6”.

2. What is the strength of the relationship between RPE and ACV in the front squat and HHBD in four repetitions-to-volitional fatigue sets with 80% 1-RM?

Hypothesis #2: The front squat and HHBD will have a strong inverse correlation between RPE and velocity in all four repetitions-to-volitional fatigue sets with 80% 1-RM.

3 Methods

3.1 Participants

An a priori power analysis (G*Power v. 3.1.5.1) indicated that 27 participants were required for the study. This calculation was based on a medium effect size (Cohen’s d = 0.50), an alpha level of .05, and a ß-value of 0.8 employing a paired-sample t-test statistical approach. Twenty-seven participants (14 male, 13 female) were recruited from local fitness centers in Regina, Saskatchewan, Canada (Table 1). Inclusion criteria included performing resistance training for ≥ 6 months prior to the start of the study and being able to front squat 1.5x their body mass and HHBD 2x their body mass. At baseline, participants were required to fill out a leisure time exercise questionnaire which indicated the average number of times that strenuous (i.e. heart beats rapidly), moderate (i.e. not exhausting), and mild exercise (i.e. minimal effort) was performed per week (Appendix A; Godin & Shephard, 1985). The Research Ethics Board at the University of Regina approved this study and participants were informed of the risks and purposes of the study before their written consent was obtained.
Table 1

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (years) M ± SD</th>
<th>Weight (kg) M ± SD</th>
<th>Height (m) M ± SD</th>
<th>FS 1RM (kg) M ± SD</th>
<th>HHBD 1RM (kg) M ± SD</th>
<th>Relative FS 1RM M ± SD</th>
<th>Relative HHBD 1RM M ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>28.9 ± 5.7</td>
<td>89.9 ± 11.9</td>
<td>1.74 ± 0.1</td>
<td>160.2 ± 24.3</td>
<td>267.1 ± 38.0</td>
<td>1.78 ± 0.2</td>
<td>3.0 ± 0.3</td>
</tr>
<tr>
<td>(n=14)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Females</td>
<td>30.1 ± 5.4</td>
<td>64.2 ± 9.0</td>
<td>1.60 ± 0.1</td>
<td>102.9 ± 14.8</td>
<td>159.2 ± 22.3</td>
<td>1.6 ± 0.2</td>
<td>2.5 ± 0.3</td>
</tr>
<tr>
<td>(n=13)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined</td>
<td>29.5 ± 5.6</td>
<td>77.1 ± 10.5</td>
<td>1.70 ± 0.1</td>
<td>131.6 ± 19.6</td>
<td>213.2 ± 30.2</td>
<td>1.69 ± 0.2</td>
<td>2.75 ± 0.3</td>
</tr>
<tr>
<td>(n=27)</td>
<td></td>
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</tr>
</tbody>
</table>

M ± SD: mean ± standard deviation
FS (Front Squat), HHBD (High-handle hexagonal Bar Deadlift), kg (Kilograms), 1RM (1-Repetition Max).
3.2 Experimental Design

Participants performed 3 sessions over the course of the study. During session one, participants performed a standardized five-minute dynamic warmup, followed by validated (Zourdos et al., 2016b) 1-RM testing for the front squat and HHBD. Forty-eight hours later, participants performed session two, in which they performed four sets to volitional fatigue in either the front squat or HHBD at 80% 1-RM. During each of the sets, participants verbally indicated when they believed they were at a “6” and “9” RPE to the researcher. In the third session, participants performed the opposite exercise not performed in session 2. The order in which the exercises were performed in sessions two and three were counterbalanced, as well as the order that 1-RMs were tested in session two. A timeline of the protocol can be seen in Table 2.
Table 2

*Timeline of Events*

<table>
<thead>
<tr>
<th>Monday (Session #1)</th>
<th>Tuesday (Session #2)</th>
<th>Wednesday (Session #2)</th>
<th>Thursday (Session #3)</th>
<th>Friday (Session #3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 1RM Testing</td>
<td>• TP</td>
<td></td>
<td>• TP</td>
<td></td>
</tr>
<tr>
<td>• AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Familiarization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• PAQ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• PAR-Q</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Anthropometric Measurements (AM), Physical Activity Questionnaire (PAQ), Physical Activity Readiness Questionnaire (PAR-Q), Training Protocol (TP: 4 sets to volitional fatigue at 80% of 1RM).
3.3 Procedures

3.3.1 1-RM testing

All 1-RM testing was performed based on procedures previously described (Zourdos et al. 2016b). Front squat and HHBD testing took place on the same day, and were judged by a Saskatchewan Powerlifting Association Provincial referee. Each lift was performed in accordance with the International Powerlifting Federation (IPF) regulations and only IPF-approved “unequipped” lifting material aids were permitted (knee sleeves and weightlifting belt; 2015). For the front squat, participants were required to reach a depth where the hip crease passed below the top of the knee when viewed from the lateral aspect. To begin the descent for the front squat, participants received the verbal command “squat” from the researcher and after the completion of the concentric phase, the verbal command “rack” was given for the participant to return the barbell to the rack. Next, the deadlift was deemed successful if the participant stood erect, with their shoulders and hips locked out, and if there was no downward movement of the bar during the ascent. Participants were given the verbal command “down” to return the hexagonal bar back to the floor after the completion of the concentric phase. Before 1-RM testing commenced, participants gave the investigator their previous best for weight and reps in each exercise so the investigator could calculate an estimated 1-RM (e1RM). Testing for each exercise began by the participants performing five repetitions at 20% of their e1-RM, followed by three repetitions at 50% e1-RM, then two repetitions at 70% e1-RM, one repetition at 80% e1-RM, and finally, one repetition at 90% e1-RM. Following the final warmup set at 90% e1-RM, subsequent increases in 1-RM attempt were determined at the investigator’s discretion. To aid attempt selection, ACV and RPE were recorded on each repetition following the final warmup set at 90% e1-RM. Furthermore, five minutes of rest was given to each participant.
between each 1RM attempt. The validation that a true 1-RM had been achieved was if: 1) the participant reported a RPE score of “10” and the investigator determined that any increase in load would result in a failed attempt or jeopardize the participant’s safety, 2) the participant reported a “9.5” on the RPE scale and missed the subsequent load increase of 2.5 kilograms (kg) or less, 3) a participant reported a RPE of “9” or lower on the RPE scale and failed the subsequent attempt with a load increase of 5kg or less. Each successive increase in load following the final warmup set of 90% e1-RM was required to be less than or equal to the previous attempts increase in load. A Rogue Ohio Bar was used for the front squat and Legend Hexagonal Bar was used for the HHBD training protocols. Eleiko lifting discs were used and were calibrated to the nearest 0.25kg to uphold the accuracy of the load lifted.

3.3.2 Average Concentric Velocity

All participants had the ACV (m/s) of the barbell measured by the Open Barbell V3 system which has been previously validated (Goldsmith et al., 2018). The LPT was synced with a tablet application to display the ACV of all repetitions performed. The device was used in accordance with the instructions set out by the manufacturer, so that when it was attached to the barbell, a perpendicular angle was achieved during all repetitions.

3.3.3 Anthropometric Testing

Total body mass (BM; kg) was measured by a calibrated digital scale and height (cm) was measured with a measuring tape secured perpendicular to the floor. Participants were required to weigh in and measure height without shoes on.
3.3.4 Intra-set RPE Accuracy

During sessions two and three, participants performed four sets to volitional fatigue at 80% 1-RM in the front squat and HHBD. Only one exercise was performed each day and the order in which they were completed was counterbalanced.

Each session began with a standardized five-minute warmup, followed by a specific warmup on the exercise the participant was performing that day. Participants completed five repetitions at 20% 1-RM, and then three repetitions at 50% 1-RM. Next, the training protocol of four sets to volitional fatigue at 80% 1-RM was performed with five minutes of rest between sets. Repetitions were only considered valid if they were executed to the standard set out by the International Powerlifting Federation (2015).

To examine the accuracy of intra-set RPE ratings, participants were asked to verbally indicate when they believed they were at a “6” and “9” during all four sets, and then continue to volitional failure. Additionally, the RPE scale was shown and explained to all participants prior to each exercise. The investigator recorded both the predicted and actual amount of repetitions performed for analysis. Finally, the difference between the actual and predicted repetitions performed (actual repetitions – predicted repetitions) was recorded as the RPE difference (RPEDIFF) for both intra-set RPEs as an absolute value.

3.4 Statistical Analyses

There was a 3-step procedure for analyses. First, to test whether an RPE of 9 versus 6 callouts was significantly more accurate, pairwise t-test comparisons were made within each set. This was followed by the fit of a generalized linear model to the data that accounted for the clustering of observations within participants across sets and allowed for comparisons across
both conditions (9 versus 6 RPE callouts). Second, standardized mean differences were computed to illustrate the size of the difference between accuracy at the 9 versus 6 RPE callouts.

Lastly, all sets to volitional failure at 80% 1-RM were inputted in excel to calculate the ACV at RPE seven through 10. These ACVs were separated by sex and combined for averages in males, females, and a combined mean for the front squat and HHBD. The same was done for ACV at 1-RM for both males, females, and a combined mean. Finally, a Pearson correlation was calculated between RPE seven through 10 and the ACV of males, females, and their combined average. Significance was set at \( p < 0.05 \).

4 Results

4.1 RPE Callout Accuracy

Table 3 displays the mean and SD’s for females at an RPE of 6 and 9 on the front squat and the HHBD across all four sets. For the front squat, females were significantly more accurate at the 9 versus 6 RPE callout for Set 1 (0.42 versus 1.85, \( p = 0.014 \)), Set 3 (0.00 versus 0.50, \( p = 0.006 \)) and Set 4 (0.18 versus 0.69, \( p = 0.038 \)). Averaging across all sets using a general linear model that accounts for the clustering of sets and conditions within participants, the difference between 9 versus 6 RPE callout for the front squat among females was also statistically significant (0.19 versus 0.86, \( p < 0.001 \)). For the HHBD, there was improved accuracy at the 9 versus 6 RPE callout among females in Set 1 (0.31 versus 1.58, \( p = 0.003 \)), Set 2 (0.08 versus 1.17, \( p = 0.002 \)), Set 3 (0.23 versus 1.17, \( p = 0.042 \)) and Set 4 (0.23 versus 0.85, \( p = 0.005 \)) as well as across all sets as tested in the generalized linear model (0.21 versus 1.19, \( p < 0.001 \)). Across all sets, estimated effect sizes (standardized mean differences) of 0.67 were found between RPE 6 and 9 on the front squat and 0.98 on the HHBD.
Table 3

**RPE Callout Accuracy – Females**

<table>
<thead>
<tr>
<th>Exercise</th>
<th>RPE</th>
<th>Set 1 M ± SD</th>
<th>Set 2 M ± SD</th>
<th>Set 3 M ± SD</th>
<th>Set 4 M ± SD</th>
<th>Total M ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS</td>
<td>6</td>
<td>1.85 ± 1.79</td>
<td>0.38 ± 0.49</td>
<td>0.50 ± 0.50</td>
<td>0.69 ± 0.72</td>
<td>0.86 ± 0.88</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.42 ± 0.49</td>
<td>0.15 ± 0.36</td>
<td>0 ± 0</td>
<td>0.18 ± 0.57</td>
<td>0.19 ± 0.36</td>
</tr>
<tr>
<td>HHBD</td>
<td>6</td>
<td>1.58 ± 1.26</td>
<td>1.17 ± 0.90</td>
<td>1.17 ± 1.46</td>
<td>0.85 ± 1.03</td>
<td>1.19 ± 1.16</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.31 ± 0.46</td>
<td>0.08 ± 0.28</td>
<td>0.23 ± 0.42</td>
<td>0.23 ± 0.58</td>
<td>0.21 ± 0.44</td>
</tr>
</tbody>
</table>

M ± SD (mean ± standard deviation)
FS (Front Squat), HHBD (High-handle Hexagonal Bar Deadlift), RPE (Rating of Perceived Exertion)
Total (Average of all four sets)
Table 4 displays the mean and SD’s for males at an RPE callout of 9 versus 6 on the front squat and the HHBD across all four sets. For the front squat, males were significantly more accurate at the 9 versus the 6 RPE callout for all sets: Set 1 (0.00 versus 0.58, p = 0.046), Set 2 (0.00 versus 0.75, p < 0.001), Set 3 (0.17 versus 0.58, p = 0.017) and Set 4 (0.18 versus 0.92, p = 0.012). Averaging across all sets using a general linear model, the difference between 9 versus 6 RPE callout for the front squat among males was also statistically significant (0.09 versus 0.71, p < 0.001). For the HHBD, improved accuracy at the 9 versus 6 RPE callout was only observed for Set 1 (0.29 versus 1.57, p = 0.008) and Set 2 (0.31 versus 1.29, p = 0.033). Averaging across all sets, statistically significant differences were observed across the 9 versus 6 RPE callout for the HHBD (0.25 versus 1.00, p = 0.004). Overall, estimated effect sizes (standardized mean differences) of 0.62 were found between an RPE of 9 and 6 on the front squat and 0.75 on the HHBD.
Table 4

*RPE Callout Accuracy – Males*

<table>
<thead>
<tr>
<th>Exercise</th>
<th>RPE</th>
<th>Set 1 M ± SD</th>
<th>Set 2 M ± SD</th>
<th>Set 3 M ± SD</th>
<th>Set 4 M ± SD</th>
<th>Total M ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS</td>
<td>6</td>
<td>0.58 ± 0.86</td>
<td>0.75 ± 0.43</td>
<td>0.58 ± 0.76</td>
<td>0.92 ± 0.76</td>
<td>0.71 ± 0.70</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0 ± 0</td>
<td>0 ± 0</td>
<td>0.17 ± 0.37</td>
<td>0.18 ± 0.39</td>
<td>0.09 ± 0.19</td>
</tr>
<tr>
<td>HHBD</td>
<td>6</td>
<td>1.57 ± 1.40</td>
<td>1.29 ± 1.58</td>
<td>0.58 ± 0.76</td>
<td>0.54 ± 0.75</td>
<td>1.00 ± 1.12</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.29 ± 0.45</td>
<td>0.31 ± 0.46</td>
<td>0.23 ± 0.58</td>
<td>0.15 ± 0.36</td>
<td>0.25 ± 0.46</td>
</tr>
</tbody>
</table>

M ± SD: mean ± standard deviation
FS (Front Squat), HHBD (High-handle Hexagonal Bar Deadlift), RPE (Rating of Perceived Exertion)
Total (Average of all four sets)
4.2 RPE/ACV Profiling

Averages of the last successful four repetitions of each set and each exercise were divided by sex and also combined for a group average. Both males and females, as well as their combined averages, had very strong inverse relationships between RPE and ACV (Table 5). While ACVs were very similar between males and females for the HHBD, females displayed slower ACVs across all RPE values on the front squat. Females had an ACV of 0.08 m/s lower than males for RPEs 7, 8, and 9, and 0.06 m/s slower at RPE 10, which is a minimum difference of one z-score for all RPEs.

ACV at 1RM on the front squat was found to be 0.29 m/s ± 0.05 and 0.27 m/s ± 0.05 for males and females, respectively. ACV was lower for both males and females on the HHBD at 0.18 m/s ± 0.03 and 0.20 m/s ± 0.05, respectively. Combined averages on the front squat and HHBD were 0.28 m/s ± 0.05 and 0.19 m/s ± 0.05, respectively.
Table 5

**RPE/ACV Profiling**

<table>
<thead>
<tr>
<th>RPE</th>
<th>FS</th>
<th>HHBD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ACV</td>
<td>ACV</td>
</tr>
<tr>
<td>Males</td>
<td>(M ± SD)</td>
<td>(M ± SD)</td>
</tr>
<tr>
<td>Females</td>
<td>(M ± SD)</td>
<td>(M ± SD)</td>
</tr>
<tr>
<td>Combined</td>
<td>(M ± SD)</td>
<td>(M ± SD)</td>
</tr>
<tr>
<td>7</td>
<td>0.51 ± 0.05</td>
<td>0.43 ± 0.06</td>
</tr>
<tr>
<td>8</td>
<td>0.50 ± 0.06</td>
<td>0.42 ± 0.06</td>
</tr>
<tr>
<td>9</td>
<td>0.46 ± 0.06</td>
<td>0.38 ± 0.06</td>
</tr>
<tr>
<td>10</td>
<td>0.40 ± 0.06</td>
<td>0.34 ± 0.06</td>
</tr>
<tr>
<td>1RM</td>
<td>0.29 ± 0.05</td>
<td>0.27 ± 0.05</td>
</tr>
<tr>
<td>r</td>
<td>-0.97</td>
<td>-0.99</td>
</tr>
</tbody>
</table>

M ± SD (mean ± standard deviation)
AVC (Average Concentric Velocity), FS (Front Squat), HHBD (High-handle Hexagonal Bar Deadlift), r (Pearson’s Correlation), RPE (Rating of Perceived Exertion), 1RM (1-Repetition Max).
5 Discussion

The purpose of this thesis was: 1) assess the accuracy of verbal RPE callouts in the front squat and HHBD in four sets to volitional failure with 80% 1-RM and, 2) to evaluate the strength of the relationship between ACV and RPE in the front squat and HHBD. Results showed a strong inverse relationship between RPE and ACV on the front squat and HHBD and that an RPE callout of 9 is more accurate than an RPE callout of 6. On average, the RPE 9 callout for both the front squat and HHBD had a variation of 0.20 RPEs compared to 1.03 RPEs for a callout of 6. These findings support the notion that the RPE scale is more accurate if the participant lifts to volitional fatigue.

Sex differences were not found in the accuracy of RPE callouts, but ACV differences were found at RPEs 7-10 in the front squat and at an RPE of 10 on the HHBD. Females displayed slower velocities across all RPEs in the front squat when compared to males, but males displayed a slower velocity at RPE 10 on the HHBD (a minimum of one z-score difference). It is theorized that the sex differences in ACV found in the present study could be due to the training background of the participants. Nine females had CrossFit/Olympic weightlifting experience compared to 3 males. Table 5 provides a starting point for coaches and athletes to utilize the RPE scale with a higher degree of accuracy based on the ACV of their final repetition of a set.

Average differences between an RPE 7 and 8 callout (0.01 m/s) were smaller than the differences between RPE callouts of 8-10 (0.03 m/s for RPE 8 vs. 9 and 0.04 m/s for RPE 9 vs. 10). It is speculated that this could be one factor that plays into the first hypothesis where lifters are able to use the RPE scale with a higher degree of accuracy as they get closer to volitional fatigue. The ACV of the bar also slows as the lifter approaches volitional fatigue which provides valuable information to the lifter on how many repetitions they have in reserve. The RPE 8
callout looks to be the cutoff where ACVs begin to decrease exponentially to an RPE callout of 10.

This study found 1-RM velocities to be slower than their MVT (ACV at RPE 10 in a repetitions-to-failure set). In the front squat, the ACV for females was 0.27 m/s while the ACV at RPE 10 was 0.34 m/s. Likewise, males 1-RM velocity was 0.29 m/s while the ACV at RPE 10 was 0.40 m/s. A similar difference was observed on the HHBD indicating that the MVT may not represent a lifter’s 1-RM velocity. The researcher encouraged participants to exercise until volitional failure but not to fail on a repetition. This could be one factor that influenced the MVTs being faster than 1RM velocity.

Results of the present study support the previous findings of Helms et al. (2012). In both studies, the squatting variation was faster at 1-RM than the deadlifting variation. Helms et al. (2012) found an ACV at 1-RM of 0.23 m/s for back squat and 0.14 m/s for the barbell deadlift, while 1-RM velocity of the front squat in the present study was 0.28 m/s and 0.19 m/s for the HHBD. Although speculative, the slower velocities observed in the front squat may be due to a high degree of technical proficiency which is typically required in the execution of a 1RM with the barbell in the front rack position. The HHBD is an easier movement to execute with heavy loads and allows for more breakdowns in technique while still successfully completing a 1-RM.

6 Practical Applications

This study provides evidence that the utilization of the RPE scale based on RIR is more accurate at higher RPEs versus lower RPEs. Practitioners who want to utilize the RPE scale to autoregulate training intensity should use caution when prescribing RPEs as low as 6. Utilizing higher RPEs will produce more accurate training intensities and will allow lifters to
autoregulate training load to achieve the desired stress the practitioner has programmed on a day to day basis.

Secondly, when utilizing a LPT to autoregulate training intensity, RPEs of \( \leq 7 \) should be used with caution as an RPE of 8 seems to be the cutoff where ACV better represents the associated RPE scale number. RPE 7 and 8, on both front squat and HHBD, showed ACVs that only differed by 0.01 m/s, whereas RPEs 8-10 had more variation making them easier to differentiate and utilize the RPE scale with a higher degree of accuracy. Also, females may need to use a different ACV/RPE profile for the front squat, but further research is needed before recommending this.
References


Pritchett, R. C., Green, J. M., Wickwire, P. J., & Kovacs, M. S. (2009). Acute and session RPE responses during resistance training: Bouts to failure at 60% and 90% of 1RM. *South African Journal of Sports Medicine, 21*(1).


Appendix A: Godin Leisure-Time Exercise Questionnaire

Godin Leisure-Time Exercise Questionnaire

INSTRUCTIONS

In this excerpt from the Godin Leisure-Time Exercise Questionnaire, the individual is asked to complete a self-explanatory, brief four-item query of usual leisure-time exercise habits.

CALCULATIONS

For the first question, weekly frequencies of strenuous, moderate, and light activities are multiplied by nine, five, and three, respectively. Total weekly leisure activity is calculated in arbitrary units by summing the products of the separate components, as shown in the following formula:

Weekly leisure activity score = (9 × Strenuous) + (5 × Moderate) + (3 × Light)

The second question is used to calculate the frequency of weekly leisure-time activities pursued “long enough to work up a sweat” (see questionnaire).

EXAMPLE

Strenuous = 3 times/wk
Moderate = 6 times/wk
Light = 14 times/wk

Total leisure activity score = (9 × 3) + (5 × 6) + (3 × 14) = 27 + 30 + 42 = 99

Godin Leisure-Time Exercise Questionnaire

1. During a typical 7-Day period (a week), how many times on the average do you do the following kinds of exercise for more than 15 minutes during your free time (write on each line the appropriate number). Times Per Week

a) STRENUEOUS EXERCISE
   (HEART BEATS RAPIDLY)
   (e.g., running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling)
b) MODERATE EXERCISE  
(NOT EXHAUSTING) 
(e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing)

c) MILD EXERCISE  
(MINIMAL EFFORT) 
(e.g., yoga, archery, fishing from river bank, bowling, horseshoes, golf, snow-mobiling, easy walking)

2. During a typical 7-Day period (a week), in your leisure time, how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)?

<table>
<thead>
<tr>
<th></th>
<th>OFTEN</th>
<th>SOMETIMES</th>
<th>NEVER/RARELY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B: PAR-Q & YOU

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
2. Do you feel pain in your chest when you do physical activity?
3. In the past month, have you had chest pain when you were not doing physical activity?
4. Do you lose your balance because of dizziness or do you ever lose consciousness?
5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
7. Do you know of any other reason why you should not do physical activity?

If you answered YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and these questions. You answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 140/90, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- If you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional about it. Ask whether you should change your physical activity plan.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ________________________________________________ DATE __________

SIGNATURE ________________________________________________ WITNESS ________________________________________________

SIGNATURE OF PARENT or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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Supported by Health Canada Santé Canada
Appendix C: Research Participant Information and Consent Form

Title of the study: EXERTION/VELOCITY PROFILING AND ASSESSMENT OF ACCURACY OF INTRA-SET RATING OF PERCEIVED EXERTION IN THE FRONT SQUAT AND HEXAGONAL BAR DEADLIFT

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INTRODUCTION
You are being invited to participate in this research study because we are interested in investigating the relationship between average concentric velocity and rating of perceived exertion in the front squat and high-handle hexagonal bar deadlift (HHBD) and to examine the accuracy of intra-set RPE ratings in trained males and females (defined as the ability to front squat 1.5 times your body weight and HHBD 2 times your body weight).

Before you decide to participate, it is important that you understand what the research involves. This consent form will tell you about the study, why the research is being performed, what will happen to you during the study, and the possible benefits, risks, and discomforts.

If you wish to participate, you will be asked to sign this form. Your participation is completely voluntary, so it is up to you to decide whether or not to participate in this study. If you decide to take part in this study, you are free to withdraw at any time without giving any reasons for your decision and your choice not to participate will not affect your relationship with any of the researchers or institutions conducting the research. Please take time to read the following information carefully. You can ask the researcher to explain any words or information that you do not clearly understand. You may ask as many questions as you need. Please feel free to discuss this with your family, friends or family physician before you decide.

Why is this study being done?
The primary purposes of this study are: 1) to examine the accuracy of intra-set rating of perceived exertion across multiple sets to volitional fatigue at 80% 1-repetition maximum (1-RM) in the front squat and HHBD and, 2) to determine the relationship between average concentric velocity and RPE in the front squat and HHBD.
Who can participate in this study?
You can participate if you are 18-39 years of age, have been performing resistance training ≥ 6 months, and have the ability to front squat 1.5 times your body weight and HHBD 2 times your body weight. You can also participate if you are not taking medications that affect muscle biology (i.e. corticoids); if you do not have a history of fragility fractures; if you do not have diseases that are known to affect muscle biology; or if you do not have osteoarthritis.

What does the study involve?
If you agree to participate in this study, the following will occur:

You will also be given a questionnaire (Physical Activity Readiness Questionnaire), which assesses whether you are at a health risk for participating in exercise training. If you indicate a possible health risk, you will be given a clearance form (PARMED-X) to be filled out by your family physician before being permitted to participate in this study.

You will be given a physical activity questionnaire at the start of the study. This will gather information about leisure, household and work-related physical activity over the past 7 days. The frequency (number of days a week) and duration (daily hours) of specific activities performed will be recorded.

You will participate in 4 sessions.
Session 1: You will perform a familiarization trial of the front-squat and HHBD.

Session 2. At least 48 hours after session 1, you will perform initial testing. You will perform a standardized five-minute dynamic warm-up, followed by 1-RM testing for the front squat and HHBD.

Session 3: At least 48 hours after session 2, you will perform 4 sets to volitional fatigue for either the front squat or HHBD at 80% 1-RM. During each of these sets, you will verbally indicate when you believe you are at a “6” and “9” RPE to the researcher.

Session 4. At least 48 hours after session 3, you will perform 4 sets to volitional fatigue for the opposite exercise used during session 3 at 80% 1-RM. During each of these sets, you will verbally indicate when you believe you are at a “6” and “9” RPE to the researcher.

Study measurements:

Average concentric velocity for all repetitions during 1-RM testing as well as all repetitions in the front squat and HHBD protocol of 4 sets to volitional fatigue with 80% 1-RM will be measured using an open-barbell accelerometer.

RPE scores will be recorded during 1-RM testing and analyzed for accuracy at RPE 6 and 9 during the training protocol in the front squat and HHBD.

What are the benefits of participating in this study?
You may gain a better understanding of how barbell velocity corresponds to your RPE scores from participation in this study. These results are not guaranteed.

What are the possible risks and discomforts?
The resistance training and strength testing may result in minor muscle pulls and strains. You will be given proper warm-up prior to exercising and be supervised and this will minimize the risk. Adequate rest will be given between training and testing sessions to ensure that your muscles are recovered by the next training session.

What happens if I decide to withdraw?
Your participation in this research is voluntary. You may withdraw from this study at any time. You do not have to provide a reason. Your relationships with the researchers or the university will not be affected. If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during your enrolment will be retained for analysis unless you withdraw from the study by March 1, 2019.

What happens if something goes wrong?
In the case of a medical emergency related to the study, you should seek immediate care and, as soon as possible, notify the principal investigator. Inform the medical staff you are participating in a research study. Necessary medical treatment will be made available at no cost to you. By signing this document, you do not waive any of your legal rights against the sponsor, investigators or anyone else.

What happens after completion of the study?
We will inform you of the overall study results after we have analyzed all data.

What will the study cost me?
You will not be charged for any research-related procedures. You will not be paid for participating in this study. Reimbursement for study-related expenses (e.g. travel, meals) is not available.

Will my participation be kept confidential?
In Saskatchewan, the Health Information Protection Act (HIPA) defines how the privacy of your personal health information must be maintained so that your privacy will be respected. Your name will not be attached to any information, nor mentioned in any study report, nor be made available to anyone except the research team. It is the intention of the research team to publish results of this research in scientific journals and to present the findings at related conferences and workshops, but your identity will not be revealed.

Who do I contact if I have questions about the study?
If you have questions concerning the study you can contact Dr. Darren Candow at 306-585-4906 or 306-209-0280 (24 hour cell).

If you have any questions about your rights as a research subject or concerns about this study, you may contact the Chair of the University of Regina Research Ethics Board at (306) 585-4775 or email research.ethics@uregina.ca. Out of town participants may call collect.
Consent statement

I have read (or someone has read to me) the information in this consent form.
I understand the purpose and procedures and the possible risks and benefits of the study.
I have been informed of the alternatives to the study.
I was given sufficient time to think about it.
I had the opportunity to ask questions and have received satisfactory answers.
I am free to withdraw from this study at any time for any reason and the decision to stop taking part will not affect my future relationships at the university.
I agree to follow the principal investigator's instructions and will tell the principal investigator at once if I feel I have had any unexpected or unusual symptoms.
I have been informed there is no guarantee that this study will provide any benefits to me.
I give permission for the use and disclosure of my de-identified personal health information collected for the research purposes described in this form.
I understand that by signing this document I do not waive any of my legal rights.
I will be given a signed and dated copy of this consent form.
I give permission for my family physician to be informed about my participation in this study if need be:
☐ Yes
☐ No
☐ I do not have a family physician

☐ I agree to participate in this study:

Printed name of participant: _______________________________________________
Signature ______________________  Date_____________________________
Printed name of person obtaining consent: ___________________________________
Signature ______________________  Date_____________________________