The Training of a Para Powerlifter: A Case Study of Adaptive Monitoring, Training and Overcoming

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The Training of a Para Powerlifter: A Case Study of Adaptive Monitoring, Training and Overcoming

A dissertation presented to the faculty of the Department of Exercise and Sport Science East Tennessee State University

In partial fulfillment of the requirements for the degree of Doctor of Philosophy in Sport Physiology and Performance

by Derek Ryan Wilcox December 2019

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Key Words: Para-Powerlifting, Bench Press, Velocity, Grip, Paralympic, Fatigue, Athlete, Monitoring
ABSTRACT

The Training Of A Para Powerlifter: A Case Study Of Adaptive Monitoring, Training and Overcoming

by

Derek Ryan Wilcox

Paralympic athletes (PA) appear to be more prone to chronic overuse injuries from daily wheelchair or crutch use. Over half of these injuries are shoulder related which can deleteriously impact quality of life. Adaptive powerlifters (AP) are a subdivision of Paralympic athletes and are at a higher risk for catastrophic injuries as compared to their counterparts, due to the compound of fatigue and lifting of maximal weights. For this reason, it is vital to have well-designed training plans for these athletes in order to preserve quality of life and maximize performance in competition. Unfortunately, there is a lack of literature on training adaptive athletes for performance. The purpose of this dissertation is to collect and analyze monitoring data of a para-powerlifter preparing for competition over the course of a six-month macrocycle. Specifically, the intention is to 1) explore options in adaptive monitoring measures for the adaptive athlete community via para-powerlifting 2) analyze trends in the training process with such monitoring methods in fatigue and performance and 3) examine efficient and safe training methods and practices for para-powerlifting. The major findings of this dissertation are 1.) Hand grip dynamometry may be a valid monitoring tool used to gain clarity on neuromuscular fatigue within para-powerlifters. 2.) Barbell velocities may reveal trends in fatigue and recovery over the course of a training cycle for para-powerlifters. 3.) Para-powerlifters and para-athletes training
for upper-body power development should likely perform bench press using a strap to secure them to the bench for enhanced stability. The significant and consistently increased force outputs the added stability enables the athlete to utilize may bring more pronounced training adaptations towards their goals. This dissertation is exploratory in nature and much more research needs to be done to give the adaptive athlete population adequate information and tools for their long-term success and safety.
DEDICATION

This dissertation is dedicated to my parents for their support and my father’s influence leading me through the lessons of life through sport.

This dissertation is also dedicated to my coaches through the years who in their own ways taught me the potential impact a coach can have on benefitting a young athlete.

Lastly, I dedicate this dissertation to the ETSU faculty of the sport physiology and sport kinesiology graduate program for their wisdom, compassion and sharing their passion for furthering the field of sport science.
ACKNOWLEDGEMENTS

Dr. Brad DeWeese for his passion for coaching and improving the lives of athletes first and foremost.

Dr. Jeremy Gentles for his expertise in research and commitment to this project.

Meg Stone for her passion for everything she does in life and introducing me to the world of adaptive sport.

Dr. Larry Judge for sharing his expertise and wisdom in adaptive sport.
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CHAPTER 1
INTRODUCTION

Paralympic athletes (PA) are likely to face chronic overuse injuries from daily wheelchair or crutch use (Curtis, 1999. Nichols, 1979. Curtis, 1985). Over 50% of these injuries are shoulder related and directly impact daily life for these athletes (Ferrara, 1992). Adaptive powerlifters (AP) are a subdivision of Paralympic athletes and are at high risk for catastrophic injuries due to fatigue and lifting maximal weights. For this reason, it is vital to have well-designed and adaptive training plans for these athletes to preserve quality of life and maximize performance in competition. Unfortunately, there is a lack of literature on training adaptive athletes for performance.

Muscle imbalances of the shoulder are a major issue in PA. Healthy PA typically have stronger shoulders than able-bodied athletes, yet when they have chronic impingement or overuse injuries, they show comparative weakness (Burnham, 1993). Weakness and fatigue are strong factors in the likelihood of an injury and should be monitored for injury prevention and long-term development of the athlete (Dugan, 2000).

The importance of recovery is critical to the success or failure of any athlete (Sands, Stone 2005). Augmenting adaptation from stressors is vital in performance and athletes, coaches, and sport scientists have used monitoring methods to optimize adaptation with the fitness-fatigue paradigm theory in mind. Monitoring methods can help assist sport practitioners by providing a tool that can help assess an athlete’s state of recovery. All athletes respond individually to any training stimulus and programming largely due to genetic variations and experience levels (Vlietinck, & Beunen, 2004). Fatigue also largely impacts athletes individually (Mujika et al.,
2004). These variables combined with the variability of the specific conditions athletes contend with in para-powerlifting make individualized monitoring methods needed.

It is important for athletes to balance training stress and subsequent recovery. When an athlete is exposed to a stressor for too long a state of overtraining can occur (Lehmann et al., 1999). Recovery is no different. If an athlete is not exposed to the stressor enough a state of detraining can occur. Therefore, monitoring should be a continuous process that includes physiological and psychological parts (Hooper et al., 1999; Kellmann et al., 2001).

Paralympic powerlifting is a competitive sport which is contested through the bench press event. These competitions are primarily sanctioned by the International Paralympic Committee (IPC) and its affiliates. The competition is divided into sex and weight classes. As of 2019, the men’s divisions are separated into the 49, 54, 59, 65, 72, 80, 88, 97, 107, 107+ kilogram classes. The women’s divisions are separated into the 41, 45, 50, 55, 61, 67, 73, 79, 86, 86+ kilograms. Bodyweight additions are made for competitors with amputations ranging from 0.5 kg for ankle amputation up to 3 kg for complete hip disarticulation. Specialized bench press tables are used in IPC competitions that enable athletes’ easy access to the bench press surface as well as accompanying Velcro straps that secure the lifter in place for stability and safety.

The basic rules of IPC competition bench press include the athlete receiving the weight at arm’s length and receiving an audible “Start” command from the head judge once control is established. The athlete then lowers the weight until the barbell contacts the chest for a fully controlled and visible stop. Once a definitive break between the eccentric and concentric movement has been established, the athlete then presses the weight back to arm’s-length. An audible “rack” command is then given by the head judge once the athlete has displayed that the bar is under control with elbows locked (IPC Powerlifting Rules & Regulations 2013-2016).
The purpose of this dissertation is to collect and analyze monitoring data of a para-power lifter preparing for competition over the course of a six-month macrocycle. Specifically, the intention is to 1) explore options in adaptive monitoring measures for the adaptive athlete community via para-powerlifting 2) analyze trends in the training process with such monitoring methods in fatigue and performance and 3) examine efficient and safe training methods and practices for para-powerlifting.
Classification of Paralympic Powerlifters

Classification of powerlifting in the Paralympic Games determines who is eligible to compete in the sport at their given weight class. The purpose of classification is to help athletes compete fairly against each other. To be deemed eligible, an athlete must meet two requirements of the International Paralympic Committee. First, the athlete must demonstrate one of the eligible impairments listed in Table 1. Secondly, the impairment must meet the minimum disability criteria. Table 1 provides a definition and examples of the impairments that are Eligible Impairments in IPC Powerlifting provided by the IPC Powerlifting Classification Rules and Regulations (2015):

Table 2.1 Eligible Impairments in IPC Powerlifting

<table>
<thead>
<tr>
<th>Impairment type</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertonia</td>
<td>Functions related to the tension present in the resting muscles and the resistance offered when trying to move the muscles passively. Includes functions associated with the tension of isolated muscles and muscle groups, muscles of one limb, one side of the body and the lower half</td>
<td>Cerebral palsy, stroke, acquired brain injury, multiple sclerosis</td>
</tr>
<tr>
<td>Impairment</td>
<td>Functions</td>
<td>Impairments or Conditions</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
</tr>
<tr>
<td>Ataxia</td>
<td>Functions associated with control over and co-ordination of voluntary movements and of complex voluntary movements, co-ordination of voluntary movements, supportive functions of arm or leg, right left motor co-ordination, eye hand co-ordination, eye foot co-ordination, Impairments such as control and coordination problems</td>
<td>Ataxia resulting from cerebral palsy, brain injury, Friedreich’s ataxia, multiple sclerosis, spinocerebellar ataxia</td>
</tr>
<tr>
<td>Athetosis</td>
<td>Functions of unintentional, non or semi-purposive</td>
<td>Chorea, athetosis e.g., from cerebral palsy</td>
</tr>
<tr>
<td>Limb Deficiency</td>
<td>Structure of shoulder region; Structure of upper extremity; Structure of pelvic region; Structure of lower extremity In particular total or partial absence of the bones or joints of the shoulder region, upper extremities, pelvic region or lower extremities</td>
<td>Amputation resulting from trauma or congenital limb deficiency (dysmelia).</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>Impaired passive range of movement</td>
<td>Mobility of a single joint Functions of the range and ease of movement of one joint. Arthrogryposis, ankylosis, scoliosis IPC</td>
<td>Arthrogryposis, ankylosis, scoliosis IPC</td>
</tr>
<tr>
<td>Impaired muscle power</td>
<td>Muscle power functions:</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Functions related to the force generated by the contraction of a muscle or muscle groups.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inclusions: functions associated with the power of specific muscles and muscle groups, muscles of one limb, one side of the body, the lower half of the body, all limbs, the trunk, and the body as a whole.</td>
<td></td>
</tr>
</tbody>
</table>

Impairments such as Spinal cord injury, muscular dystrophy, brachial plexus injury, Erb palsy, polio, Spina bifida, Guillain-Barré syndrome.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg length difference</td>
<td>Bones of thigh; Bones of lower leg, Bones of ankle and foot. Aberrant dimensions of bones of right lower limb OR left lower limb Inclusions: shortening of bones of one lower limb Exclusions: shortening of bones of both lower limbs; any increase in dimensions</td>
<td>Congenital or traumatic causes of bone shortening in one leg</td>
</tr>
<tr>
<td>Short stature</td>
<td>Standing height is reduced due to aberrant dimensions of bones of upper and lower limbs or trunk, for example due to achondroplasia or pituitary gland dysfunction.</td>
<td>Achondroplasia, pituitary gland dysfunction</td>
</tr>
</tbody>
</table>
Paralympic powerlifting is a quickly growing adaptive sport yet very little information is available on the training of disabled athletes for competition (“1964-2012 Games Growth and Evolution”, 2014). Coinciding with the increased participation rates, so too are competitive loads increasing shown in Table 2.2 (Prystupa, 2006).

Table 2. 2 Winners 10th-12th Paralympics in selected events (Prystupa, 2006)

<table>
<thead>
<tr>
<th>Paralympic Games</th>
<th>100m run</th>
<th>Long jump</th>
<th>Throws (m)</th>
<th>50m swimming (s)</th>
<th>Powerlifting (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Men</td>
<td>Women</td>
<td>Men</td>
</tr>
<tr>
<td>T11</td>
<td>11.66</td>
<td>13.65</td>
<td>14.45</td>
<td>5.74</td>
<td>26.84</td>
</tr>
<tr>
<td>T12</td>
<td>12.61</td>
<td>15.59</td>
<td>15.69</td>
<td>5.73</td>
<td>25.55</td>
</tr>
<tr>
<td>T53</td>
<td>11.37</td>
<td>12.51</td>
<td>15.04</td>
<td>6.06</td>
<td>31.73</td>
</tr>
<tr>
<td>T36-38</td>
<td>11.22</td>
<td>11.85</td>
<td>15.63</td>
<td>6.16</td>
<td>34.78</td>
</tr>
<tr>
<td>T42-46</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T56-58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T36-38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5 Free style</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5 Backstroke</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

The sport of adaptive powerlifting by nature combined with the training of AP in general demand steps be taken for improved performance in competition and to preserve quality of life for the athletes (Pierce, 2015). What information there is on PA includes higher occurrences of chronic injury from overuse and imbalances from wheelchair and/or crutch use for daily activity (Burnham, 1993, Curtis, 1999; Hanada, 1993; Ferrara, 1990; Ferrara, 1992). Injuries of this nature directly inhibit day-to-day activity for AP by increasing difficulty of simple tasks in everyday life.

**High Performance and Higher Risk**

With regard to the highest level of competition (Van de Vliet, 2012), AP experience even higher intensity stresses than able-bodied bench press athletes. This is evidenced by the difference in world record performances in most weight classes (Tables 2.2&2.3) (Para Powerlifting Records, 2017. IPF Powerlifting Records, 2017). This is also demonstrated
regardless of drug testing protocols for the athletes in the all-time open bench press world records (Table 2.4). Three of these open classification records are held by AP in the IPC (Men's Raw World Records, 2017).

Table 2.3 Para Powerlifting Records (Para Powerlifting Records, 2017)

Table 2.4 IPF Bench Press Records (IPF Powerlifting Records, 2017)

Table 2.5 Para Powerlifting and Powerlifting Bench Press Records Combined (Men's Unequipped Bench Press World Records *in pounds*, 2017)
As a result of these increased stresses on AP, injuries are frequent and also correlated to total volume loads related to their daily movement mechanics. An epidemiological look at the injuries’ from the 2012 London Paralympic games showed that the most commonly injured area was the shoulder followed by the chest and then the elbow (Willick, 2015). The trend of soft tissue chronic injuries to the shoulder region of crutch and wheelchair dependent PA has been consistently observed for decades (Nichols, 1979. Curtis 1985). Able-bodied powerlifters without the chronic and repetitive overuse issues AP have are also shown to have shoulder imbalances making it reasonable to believe bench press training and constant crutch/wheelchair use compound these issues for AP (Cutufello, 2017). The accumulation of fatigue from the combination of volume loads of daily locomotion stress outside of training and bench press training can quickly lead to overtraining (Ferrara, 1992. Stone, 1998).

**General Adaptation Syndrome**

The general adaptation syndrome (GAS) model of stress, recovery and adaptation over time provides a framework for observing and predicting fatigue and performance trends in training (Kiely, 2012).
The original GAS model developed by Hans Selye was more generalized in application focusing on stresses in animals being exposed to different agents and disease (Selye, 1951). Parallels have been consistently drawn to strength training showing these same trends of training stimulus and recovery followed by metabolic and neuromuscular adaptations (Egan, B. 2013). Using this basis of pattern in physiological responses as a guide, with the proper methods the same trends should be able to be seen in the training of athletes. GAS is widely considered as the basis for modern periodization (Cunanan, 2018). The same parallels for able bodied athletes may be able to be drawn to PA as well increasing the level of information available for coaches.

**Block Periodization**

With the increased risks associated with fatigue related injuries in paralympic powerlifting the need for efficient, effective, and evidence-based training methods is a high priority. Fatigue has been consistently correlated with too-frequent high levels of volume and intensity (Dugan, 2000; Vetter, 2010). Efficiency in limiting accumulated fatigue and improving
sport performance is vital to the long-term development of AP. Since the prime movers for AP are the same in their competition event and daily locomotion, the repercussions of poor training design and overtraining are much higher than able-bodied athletes. This requires a training system proven to achieve optimal long-term results as well as effectively managing fatigue levels.

Block periodization fits this definition accurately (DeWeese, 2013; Plisk, 2003; Stone, 1981; Stone, 2007). Specifically, phase potentiating block periodization divides the training process into 4 specific phases.

1. General Preparation phase consists of the least specific training toward the sport of choice and aims to use high concentrated volume loads to increase strength endurance and work capacity.

2. Special preparation phase serves as a transition into moderate to high volume loads and slightly more specific training to the desired sport.

3. Competition Phase moves to low volume, high intensity training with very high sport specificity. This phase ends with a taper into the intended competition with the intent of eliminating as much fatigue as possible and allowing the accumulated training effects to manifest the training adaptations and preparedness for the best performance possible at the right time.

4. A period of Active Rest is taken to reduce fatigue completely and allow the athlete to recover mentally after competing (Stone, 2007. Mujika, 2004).
After the competition has concluded a period of Active Rest is taken to reduce fatigue completely and allow the athlete to recover mentally after competing.

The sequencing of these phases in block periodization creates a potentiating effect where one phase stimulates training adaptations that build into greater potential adaptations in the following phase. This seems to be accomplished by the concentrated loads of the training phases creating residual effects that are built on by the next phase’s concentrated loads. This sequencing creates a unidirectional progression through a macrocycle leading to a performance peak at competition manifesting the summated training adaptations that compound over this time (DeWeese, 2015). A portion of these concentrated loads include functional overreaches where the training volume and intensity are at their highest together creating a large disruption to homeostasis. This training stimulus is substantial in stimulating more adaptation but also not sustainable for very long due to accumulated fatigue. Once training intensities and volume has been decreased and returned to normal a super compensation effect is likely to occur bringing a sharp increase in the traits that were being trained during that overreach (Stone, 1991).
Functional overreaches followed by a sharp taper are widely used in the sport of powerlifting to potentiate the best performance possible in competition (Grgic, 2017).

Painter et al (2012) showed the efficiency of block periodization success in producing statistically similar gains in strength in NCAA Division 1 collegiate throwers across training groups using block periodization and daily undulating periodization (DUP). However, the DUP group also required a 55% higher volume load to achieve these similar results and were accompanied by higher injury rates (Painter, 2012). Achieving good results from training with less total volume for AP would seem to be a great benefit as most of the population adds additional volume on their bench pressing musculature just from daily locomotion on crutches or wheelchair use.

**Potential Monitoring Methods for Adaptive Powerlifters**

**Importance of monitoring**

The importance of recovery is critical to the success or failure of any athlete (Sands, Stone 2005). Augmenting adaptation from stressors is vital in the performance and athletes, coaches, and sport scientists have used monitoring methods to optimize adaptation with the fitness-fatigue paradigm theory in mind. Monitoring methods can help assist sport practitioners by providing a tool that can help assess an athletes’ state of recovery. All athletes respond individually to any training stimulus and programming largely due to genetic variations and experience levels (Huygens, 2004). Fatigue also largely impacts athletes individually (Mujika, 2004). These variables combined with the individuality of every athlete creates the need for individual monitoring during the training process.

It is important for athletes to balance training stress and subsequent recovery. When an athlete is exposed to a stressor for too long a state of overtraining can occur (Lehmann et al.,
Recovery is no different. If an athlete is not exposed to the stressor enough a state of detraining can occur. Therefore, monitoring should be a continuous process that includes physiological and psychological parts (Hooper et al., 1999; Kellmann et al., 2001).

Monitoring Techniques

Monitoring training load can help coaches and practitioners use a scientific method to explain changes in performance. From data collected through monitoring athletes, coaches and practitioners can load-performance relationships, and it can also help develop and alter training programs to optimize performance in competitions. Monitoring can also help minimize injury, illness and non-functional over-reaching.

Availability of resources regarding time, money and instruments may play a factor in whether a coach or athlete utilizes monitoring within their training program. Coaches that do not have a background in sport-science may find monitoring overwhelming, particularly if that coach is on a voluntary basis and the amount of available time is an issue. Below is a discussion on how questionnaires, bar velocity and dynamometers can be beneficial when monitoring Paralympic athletes.

Questionnaires

Questionnaires and logs can be a simple cost effecting way to monitor training and subsequent responses to a type of training. The drawback of questionnaires and logs is that they rely on subjective information obtained from the athlete. It may be that this subjective data be corroborated with other monitoring tools. Athletes may under/overestimate data that could alter the training load. It is important to note that if this type of monitoring tool is used the frequency and length of administration should be considered to maximize the information given and avoid redundancy in athlete feedback (Taylor, 2012).
There are various questionnaires that have been utilized in the literature by coaches and practitioners. These include the Profile of Mood States (POMS) (Morgan, 1987), The Recovery-Stress Questionnaire for athletes (REST-Q-Sport) (Kellmann, 2000), Daily Analysis of Life Demands for Athletes (DALDA) (Rushall, 1990), and the Total Recovery Scale (TQR) (Kentta, 1998).

Questionnaires can provide simple and useful information but many factors should be considered when administering them to athletes (Borresen, 2009). Frequency, time taken to complete, type of response required (written vs circling), time of day (consistent) are all factors that should be considered when choosing the right type of questionnaire (Halson, 2014).

**Rating of Perceived Exertion**

Borg’s rating of perception of effort (RPE) is one of the most common ways of assessing internal load. The use of RPE is an easy and cost-effective way of collecting data that can tell coaches and practitioners the athletes perception on exercise intensity (Borresen, 2009). RPE is subjective as it relies on the notion that the athlete can monitor their own physiological stress during exercise and retrospectively report that information post-training or competition (Chen, 2002). It should be noted that RPE could fluctuate due to adaptive powerlifters needing to use their prime movers for mobility purposes which would likely cause more fatigue than what an able-bodied powerlifter would endure (Borresen, 2009).

Session RPE is a way to monitor training load for the entire training session which entails multiplying the athlete’s RPE by the duration of the training session in minutes. This method has been shown to be valid and reliable is various sports including both team and individual sports (Foster, 1998).
Due to the need for adaptive athletes to utilize their prime movers throughout the day, it may be beneficial for coaches and practitioners to utilize a combination of questionnaires, logs, and RPE’s so that the volume-load from a session can be differentiated from the volume load accumulated from daily activities.

**Load-Velocity Measurement**

Velocity measurements have been shown to predict 1RM through the load-velocity relationship. A study by Jidovtsseff et al (2011) showed this in recreationally active subjects. A 1RM concentric-only bench press was conducted during the first session and approximately one week later subjects were tested on velocity measurement. Four trials between 3-40%, three trials at 50, 60, 70% 1RM, and two trials at 80, 90, and 95% 1RM.

Previous studies have suggested that movement velocity can help predict the relative load of both upper and lower body resistance exercises (García-Ramos 2018.). Creating a load-velocity profile for athletes can help coaches track an athlete over time and their progress. Load-velocity may also be used to estimate daily readiness without interfering with the prescribed load of the training session. Monitoring repetition velocity may estimate the stress induced by resistance training (8), and may be an indicator of fatigue during that exercise or training session.

PUSH (PUSH Inc, Canada) is an inertia sensor that is specifically designed to be used during resistance training. The device can be worn on the arm and can provide the coach or athlete an estimation of the movement of the barbell that is gripped with the hands. The device provides average and peak values for velocity and power on the app provided by PUSH which can be used via smartphone or tablet. A Study conducted by Sato et al. (2015) showed that the inertia sensor in the PUSH device is accurate when compared to a 3D motion capture system, but it should be noted that the study only looked at dumbbell exercises.
Eight other studies have examined the validity and reliability of the PUSH device. One study investigated movement velocity during the back squat and found that the PUSH device showed high correlations with mean (r=0.85), and peak velocity (r=0.91) when compared with a T-Force linear transducer. (Balsalobre-Fernandez 2016). Ripley and McMahon (2016) looked at the PUSH device compared to force plates when testing countermovement jumps. Within-session reliability was found for peak velocity and peak power for both the force plates and the PUSH device but the PUSH device overestimated all values compared to the force plates. Therefore, correction equations were produced.

The bench press has been used to explore the load and velocity relationship (González-Badillo. 2010; Jidovtseff, 2011) and has been widely explored (Bazuelo-Ruiz, B, 2015). The load-velocity of multi-joint exercises have been found to be highly linear (Munoz-Lopez, 2017). In one study, the mean velocity was shown to have the highest linearity of the load-velocity relationship and can be thought to be a more accurate measure for monitoring relative load (Garcia-Ramos et al.).

When measuring velocity during exercises such as the bench press is is recommended that mean velocity is used as a form of measurement over peak velocity. It is thought that mean velocity is a better example of the entire range of motion, and make analysis easier to process (Jidovtseff, 2011)

A study conducted by Gonzalez-Radillo (2010) investigated mean velocity and relative load and found that when it was attained with a given absolute load it can be an accurate estimate of the relative load (1RM) (Cronin, 2003). Therefore, it can be a practical way to monitor training load during resistance training. Mean concentric velocity has been shown to be a reliable and appropriate measure of movement velocity in exercises such as the bench press. Establishing
a load-velocity profile may give coaches an insightful comparison of the athlete’s training over time through monitoring.

**Dynamometry**

Dynamometry is often used as a measure of neuromuscular function (Jidovtseff, 2011). This involves using a handheld dynamometer and squeezing with a maximal effort. This results in a force value that can be tracked over time. This method is often used due to the simplicity of protocol and the minimal fatigue that is induced from using such a test (Twist & Highton, 2013). A hand dynamometer is an easy way for a coach to track neuromuscular function of an athlete. Mathiowetz et al., (1984) have shown that the Jamar dynamometer (Asimo Engineering) had very high inter-rater reliability and had the highest accuracy of the instruments tested in the study. The hand-held dynamometry is a reliable and valid instrument that is typically used in the clinical setting but has also been shown to useful in monitoring athletes (Twist & Highton, 2013).

**Summary**

The purpose of this review is to provide a base of information to be used toward the goal of achieving excellence in para-powerlifting and preserving quality of life for the adaptive athletes involved. It seems reasonable that the proper steps to ensure the safety of AP as well as training them to perform at the highest level possible can be achieved through properly periodized training and monitoring fatigue levels as well as progress with the different monitoring tools available. The lack of peer reviewed literature pertaining to enhancing the performance of AP leaves much to be desired in coach’s education for the sport. More research is needed to develop and refine training and coaching techniques for AP. Due to the low number in population of AP, significant sample sizes will be difficult to obtain for comparative research.
Case studies and single subject design may be required to accumulate data to further progress on this subject. Due to the nature of their lifestyles, the risks involved with making poor training decisions are higher for these athletes. Catastrophic injury in training or competition may not lead to simply time away from sport, but render the athlete essentially immobile. Fatigue and overuse seem to be the greatest factors contributing to injuries for AP. Educating coaches on these areas will also be a very important step. Periodized training encompasses all the values needed to fit the needs of AP to develop to as high a level as possible in their sport. It is shown to produce a high rate of progress compared to the work that has been done by the athlete. With this feature of fatigue management being utilized it should allow for long, healthy and successful careers for PA in the sport of para powerlifting. Coaches carry the responsibility and must be ethically accountable to provide the best training plans and safety precautions to their athletes as possible in adaptive powerlifting.
CHAPTER 3

ANALYSIS OF TRENDS IN HAND GRIP DYNAMOMETRY AND LOAD-VELOCITY MEASUREMENT IN A MACROCYCLE LEADING TO PARA POWERLIFTING COMPETITION

ABSTRACT

**Purpose:** The purpose of this dissertation is to collect and analyze monitoring data of a para-power lifter preparing for competition over the course of a six-month macrocycle. Specifically, the intention is to 1) explore options in adaptive monitoring measures for the adaptive athlete community via para-powerlifting 2) analyze trends in the training process with such monitoring methods in fatigue and performance and 3) examine efficient and safe training methods and practices for para-powerlifting.

**Methods:** One Para-powerlifter Age: 34, Male, Weight: 73-81.5kg, Height 5’2”, Previous Best competition Bench Press: 130kg at 86kg Bodyweight Was assessed over a 5 month training cycle leading into competition. Peak and Mean barbell velocities were collected at the beginning and end of each training week and Hand Grip Dynamometer testing performed before every session. Phase potentiating block periodization was utilized as the training methodology.

**Results:** Linear regression modeling and single subject Tau U calculations showed intra-week fatigue and recovery trends as well as an overall positive trend in the strength of the athlete. The athlete increased their strength to weight ratio significantly while reducing weight to a lower weight class.

**Conclusions:** Monitoring para-powerlifters with barbell velocity testing and hand grip dynamometry may give greater insight into fatigue and recovery patterns. More research is needed in the para-athlete community.
INTRODUCTION

Paralympic athletes (PA) tend to face chronic overuse injuries from daily wheelchair or crutch use. Over 50% of these injuries are shoulder related and impact daily life for these athletes (Ferrara, 1992). Adaptive powerlifters (AP) are a subdivision of Paralympic athletes and are at high risk for catastrophic injuries due to fatigue and lifting maximal weights. It is vital to have well-designed and adaptive training plans for these athletes to preserve quality of life and maximize performance in competition. Unfortunately, there is a lack of literature on training adaptive athletes for performance.

Paralympic powerlifting is a contest for adaptive athletes to compete in the bench press event. These competitions are primarily sanctioned by the International Paralympic Committee (IPC) and its affiliates. The competition is divided by gender and weight class.

Paralympic powerlifting is a quickly growing adaptive sport yet very little information is available on the training of disabled athletes for competition. With the increase in popularity and number of athletes the loads lifted by AP are also increasing (Prystupa, 2006). The sport of adaptive powerlifting demands more research be done for improved performance in competition and to preserve quality of life for the athletes (Pierce, 2015). An epidemiological look at the injuries from the 2012 London Paralympic games showed that the most commonly injured area was the shoulder followed by the chest and then the elbow (Willick, 2016). The trend of soft tissue chronic injuries to the shoulder region of crutch and wheelchair dependent PA has been observed for decades (Nichols, 1979. Curtis 1985). Since able-bodied powerlifters have demonstrated shoulder imbalances, it’s reasonable to believe that bench press training and constant crutch/wheelchair use may compound these issues for AP (Cutrufoello, 2017). The
accumulation of fatigue from the combination of volume loads of daily locomotion stress outside of training and bench press training can quickly lead to overtraining (Ferrara, 1992. Stone, 1998).

**General Adaptation Syndrome**

The general adaptation syndrome (GAS) model of stress, recovery and adaptation over time provides a framework for observing and predicting fatigue and performance trends in training (Kiely, 2012). The original GAS model developed by Hans Selye was more generalized in application focusing on stresses in animals being exposed to different agents and disease (Selye, 1951). Parallels have been consistently drawn to strength training showing these same trends of training stimulus and recovery followed by metabolic and neuromuscular adaptations (Egan, B. 2013). Using this basis of pattern in physiological responses as a guide, with the proper methods the same trends should be able to be seen in the training of athletes. GAS is widely considered as the basis for modern periodization (Cunanan, 2018).

**Block Periodization**

With the increased risks associated with fatigue related injuries in paralympic powerlifting the need for efficient, effective and evidence-based training methods is a high priority. Fatigue has been consistently correlated with frequent high levels of volume and intensity (Dugan, 2000; Vetter, 2010). Efficiency in limiting accumulated fatigue and improving sport performance is vital to the long-term development of AP. Since the prime movers for AP are the same in their competition event and daily locomotion, the repercussions of poor training design and overtraining are much higher than able-bodied athletes. This requires a training system proven to achieve optimal long-term results as well as effectively managing fatigue levels.

1. General Preparation phase consists of the least specific training toward the sport of choice and aims to use high concentrated volume loads to increase strength endurance and work capacity.

2. Special preparation phase serves as a transition into moderate to high volume loads and slightly more specific training to the desired sport.

3. Competition Phase moves to low volume, high intensity training with very high sport specificity. This phase ends with a taper into the intended competition with the intent of eliminating as much fatigue as possible and allowing the accumulated training effects to manifest the training adaptations and preparedness for the best performance possible at the right time.

4. A period of Active Rest is taken to reduce fatigue completely and allow the athlete to recover mentally after competing (Stone, 2007. Mujika, 2004).

   Importance of monitoring

The importance of recovery is critical to the success or failure of any athlete (Sands, Stone 2005). Augmenting adaptation from stressors is vital in the performance and athletes, coaches, and sport scientists have used monitoring methods to optimize adaptation with the fitness-fatigue paradigm theory in mind. Monitoring methods can help assist sport practitioners by providing a tool that can help assess an athletes’ state of recovery. All athletes respond individually to any training stimulus and programming largely due to genetic variations and experience levels (Vlietinck, & Beunen, 2004). Fatigue also largely impacts athletes individually (Mujika et al
These variables combined with the individuality of every athlete creates the need for individual monitoring during the training process.

It is important for athletes to balance training stress and subsequent recovery. When an athlete is exposed to a stressor for too long a state of overtraining can occur (Lehmann et al., 1999). Recovery is no different. If an athlete is not exposed to the stressor enough a state of detraining can occur. Therefore, monitoring should be a continuous process that includes physiological and psychological parts (Hooper et al., 1999; Kellmann et al., 2001).

**Monitoring Techniques**

Monitoring training load can help coaches and practitioners use a scientific method to explain changes in performance. From data collected through monitoring athletes, coaches and practitioners can load-performance relationships, and it can also help develop and alter training programs to optimize performance in competitions. Monitoring can also help minimize injury, illness and non-functional over-reaching. Grip dynamometry and barbell velocity monitoring during the training process may achieve these goals for the PA population.

**Load-Velocity Measurement**

Velocity measurements have been shown to predict 1RM through the load-velocity relationship. Previous studies have suggested that movement velocity can help predict the relative load of both upper and lower body resistance exercises (García-Ramos, A., Luis Pestaña-Melero, F., Pérez-Castilla, A., Javier Rojas, F., Haff, G. G.). Creating a load-velocity profile for athletes can help coaches track an athlete over time and their progress. Load-velocity may also be used to estimate daily readiness without interfering with the prescribed load of the training session. Monitoring repetition velocity may estimate the stress induced by resistance training and may be an indicator of fatigue during that exercise or training session (Jidovtseff, 2011).
PUSH (PUSH Inc, Canada) is an inertia sensor that is specifically designed to be used during resistance training. The device can be worn on the arm and can provide the coach or athlete an estimation of the movement of the barbell that is gripped with the hands. The device provides average and peak values for velocity and power on the app provided by PUSH which can be used via smartphone or tablet. A Study conducted by Sato et. al (2015) showed that the inertia sensor in the PUSH device is accurate when compared to a 3D motion capture system, but it should be noted that the study only looked at dumbbell exercises.

Table 3.1 PUSH Band Review Articles (Chapman, 2019)

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<tr>
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<tr>
<td>Sato et al.</td>
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</tr>
<tr>
<td>Ripley &amp; McMahon</td>
<td>2016</td>
<td>NSCA NatCon</td>
<td>BB Jump Squat</td>
<td>Force Plate</td>
<td>V 1.1.26</td>
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<tr>
<td>McGroth et al.</td>
<td>2018</td>
<td>J. Aust. Strength Cond.</td>
<td>BB Bench Press</td>
<td>3D Motion Capture</td>
<td>V 1.1.26</td>
</tr>
<tr>
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<td>2016</td>
<td>J. Strength Cond. Res.</td>
<td>BB Bench Press</td>
<td>Linear Position Transducer</td>
<td>V 3.1.2</td>
</tr>
<tr>
<td>Wee et al.</td>
<td>2019</td>
<td>Sport Perf. Sci. Review</td>
<td>Countermovement Jump</td>
<td>Force Plate</td>
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**Dynamometry**

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METHODS

Study Design

This was a single subject case study aimed at investigating fatigue and performance trends in the training for para-powerlifting competition. The monitoring measures implemented were designed to reflect the athlete’s preparedness to perform in contrast to the training stimulus placed on them. The measures were taken over the course of a six month macrocycle (61 total sessions) utilizing the principles of block periodization in the concurrent training phases of general preparation (less specific hypertrophy oriented), specialized preparation (moderate volume, strength oriented), and competition phase (most specific to sport, low-volume high-intensity oriented). Training was conducted 3 times a week consisting of a Heavy Push day, Heavy Pull day and a Light Push Day (repeated effort from Heavy Push with weights decreased 15%). Exercise selection was primarily compound exercises separated by push and pull movements on separate training days. Bench Press displacement was measured at the beginning of each block to track changes in range of motion due to fluctuations in the athlete’s anthropometrics. Body weight was collected after every training session.

Subject Profile

The subject observed in this case study was a 34-year-old male 5’2” in height and weighing between 73 and 82 kg. His training experience included 10 years of intermittent resistance training with the previous two years being consistently regimented. Competition experience was two local bench press competitions along with two national level para-powerlifting meets sanctioned by the IPC. Bench press displacement was measured ranging between 43 and 47 cm throughout the training process. The heaviest bench press achieved in
competition was 130 kg at a weight of 86 kg. Informed consent form was signed by the subject and approved by the IRB.

**Training Design**

Training design was broken down into the macrocycle (entire length of training into the competition through general preparation, specific preparation and competition phases), mesocycles/blocks (4-5 weeks of the same exercises with waved intensities) and microcycles (1 week of training). The primary exercise sets and reps per block were: Block: 1 (five weeks): 3-5 sets of 10 reps, Block: 2: 5 sets of 6 reps, Block 3: 5 sets of 3 reps, Block 4: 3-4 sets of 2 reps, Block 5: 3 sets of 1-2 reps. Microcycles in the block normally waved in relative intensity (Relative Intensity Load = Weekly Training Load/Peak Intensity Week Load in the same block) from: Week 1 65%, Week 2 85%, Week 3 95%, (Peak Intensity) Week 4 100%. Meet peaking Block 4 weeks before the meet waved from Week 1 85%, Week 2 95%, Week 3 100% Week 4 (taper) 80%. The planned intensity of each week was adapted over time for the specific recovery patterns of the athlete observed previously. Each microcycle consisted of 3 sessions including a Heavy Push day, Heavy Pull day and a Light Push Day (repeated effort from Heavy Push with weights decreased 15%). Push Days were based on bench press variations and Pull Days were based on either prone rows or pull up variations. The final 4-week block (Table 3) of training leading into the competition is altered to accommodate an intentional overreach in intensity followed by a taper in volume and intensity into competition day.

**Warm Up Procedures**

The common warm up protocol for all training days included grip dynamometer testing, seated shoulder circles with a 2 ½ kg plate 10 reps per side and dumbbell rows with 50 pounds
and reps per side. Bench press specific warm-ups before velocity testing included 20 kg, 40 kg, and 60 kg for 10 reps with 1-2 minutes rest followed by 80 kg for 5 reps with 2 minutes rest.

**Collection Procedures**

**Grip Dynamometer Testing**

Grip testing was performed with a Jamar dynamometer from Asimo Engineering. The subject was encouraged to squeeze as hard as possible but not allowed to hold maximum grip for more than three seconds. The testing protocol included being seated with the elbow close to the side of the torso and bent at 90°. These are adaptations from standardized protocols of grip dynamometer testing based on the American Association of hand therapists and Southampton protocols (Rollins, 2011). Grip tests were alternated left then right three times with 30 seconds in between individual tests. Reliability testing for the grip dynamometer was performed by bracing the dynamometer in a supine position between 25kg bumper plates and loading Ivanko calibrated competition disc plates on the dynamometer as carefully and gradually as possible in 10kg increments. (Table 3.2)

**Load Velocity Testing with Accelerometry**

Bench Press barbell velocity testing emulated the exact technique used in IPC competition from the rulebook (IPC, 2012). The subject was tightly secured to the bench using a leather buckled belt at mid thigh. Two sets of two reps were performed with one minute of rest in between those sets. The PUSH accelerometer unit was placed at the midline of the left forearm for all tests. Peak and mean velocities from each rep were collected and displayed on the PUSH application and recorded into Microsoft Excel.
**Subject Anthropometric Measures**

Body mass was collected and kilograms immediately after every training session had concluded. The subject was seated upon the scale in the same fashion that is weighing in for competition. Bench press displacement (bar range of motion) was collected at the beginning of every training block.

**Statistical Analysis**

Coefficient of variance was calculated for grip tests and bench press velocities. All data was recorded between February 2017 - August 2017. All statistics were calculated on Microsoft Excel 2016 (Microsoft, Redmond, WA, version 16.0.11727.20188). ICC figures were calculated through an excel spreadsheet developed by Will Hopkins (Hopkins, 2017). Grip Test and Bench Press velocity measures were analyzed via statistical process control and effect size in context of training phases, blocks and microcycles. Control Limits set at 1.5 and 2.0 standard deviations from the mean. Post hoc analysis includes bodyweight, bench press displacement and bench press velocity (peak and mean) for force and power calculations. A ratio was generated to show calculated peak force relative to the body weight for each testing session.

**RESULTS**

**Reliability of Performance Measures**

Reliability testing on the Jamar dynamometer (Table 1) used in the study showed almost perfect reliability by ICC measure. ICC values reported (Table 2) for velocity and grip strength measures showed moderate (0.5-0.75) intra-class correlations aside from the “Mean Velocity 2nd Set”. to good (> .75) intra-class correlations. All CVs for the total samples were sufficient (<10%) apart from all mean velocities together. The individual first and second sets for mean velocity data remained sufficient individually.
Post Hoc Analysis

Figure 3.4 shows the body mass measures for every training session in the training cycle. The athlete’s body weight shows a reduction over time by 7.9kg. Figure 3.5 shows the corresponding increase in relative peak force (PF= 100kg x Peak Velocity m/s) to body weight ratio over the course of the training cycle.

Table 3.2 - Dynamometer reliability testing showing excellent ICC reliability.

<table>
<thead>
<tr>
<th>Jamar Dynamometer Reliability</th>
<th>ICC</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10kg</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>20kg</td>
<td>20</td>
<td>20</td>
</tr>
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<td>30kg</td>
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<tr>
<td>50kg</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>60kg</td>
<td>61</td>
<td>62</td>
</tr>
</tbody>
</table>

Intraclass correlation (ICC) 1.000

Table 3.3 Reliability Measures for grip and velocity testing.

<table>
<thead>
<tr>
<th>Reliability Measures for Grip and Velocity Testing</th>
<th>ICC</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH Grip Test</td>
<td>0.61</td>
<td>4.66%</td>
</tr>
<tr>
<td>LH Grip Test</td>
<td>0.65</td>
<td>5.06%</td>
</tr>
<tr>
<td>Mean Vel 1st Set</td>
<td>0.81</td>
<td>8.89%</td>
</tr>
<tr>
<td>Mean Vel 2nd Set</td>
<td>0.18</td>
<td>9.95%</td>
</tr>
<tr>
<td>Peak Vel 1st Set</td>
<td>0.61</td>
<td>6.69%</td>
</tr>
<tr>
<td>Peak Vel 2nd Set</td>
<td>0.64</td>
<td>7.19%</td>
</tr>
</tbody>
</table>
Figure 3. Grip Strength trends shown by training phases the training volume across the training cycle leading to competition.
Figure 3. 2 Peak Velocity trends shown by training phases the training volume across the training cycle leading to competition.
Macrocycle Mean Velocity Tests Over Volume Load

Figure 3. 3 Mean Velocity trends shown by training phases the training volume across the training cycle leading to competition.
Figure 3.4 Showing the downward trend in bodyweight through the macrocycle of the subject’s body mass.

Figure 3.5 Showing the positive trend of 100kg Bench Press Velocity to bodyweight ratio of the subject through the macrocycle.
DISCUSSION

The Jamar dynamometer showed great reliability. The second set measures of mean bench press velocity testing showed a high amount of variability. This may be due to the one-minute rest time implemented in the design. Future research may consider lengthening the rest periods between sets more consistent data.

An important part of the statistical process control assessment is visual inspection for contextual and obvious trends (Sands 2019). Grip and velocity measures upon visual inspection have similar traits in different areas of the training cycle. In the general preparation phase there is a spike in total volume (5x10) on the week of April 3 followed by a substantial decrease for all measures indicating accumulated fatigue being high. All measures show a drastic increase in the following two weeks after this point suggesting a potential super compensation effect from the intentional overreach in training followed by lower relative intensities and volumes. In the second half of the specific preparation phase the athlete reported being sick with a common cold and sinus congestion. All measures decreased during this time compared to the previous trends reflecting inhibited preparedness to perform. Week previous on all measures before the athlete reported sick showed a decline suggesting there may be a predictability by fatigue and lowered performance measures to the athlete’s health and immune function being suppressed. The most sensitive measure to this effect seems to have been dynamometry. All measures reflected a substantially positive trend during the competition phase as volume was at its lowest but the intensity was at its highest. Only hand grip dynamometry was measured on the day of the competition which shows a potential super compensation effect following the supra-maximal overreach in intensity (Accentuated Eccentric Loading) followed by a taper.
The athlete was intentionally trying to reduce body mass as a goal to be more competitive in a lighter weight class. The athlete’s peak force to body weight ratio consistently improved throughout the training cycle which would be vital for success in weight class sports like parapowerlifting. Improving relative performance while the weight loss is occurring may suggest the efficacy of phase potentiating block periodization as being conducive for making consistent progress over time even when in a consistent calorie deficit for this athlete.

With the lack of literature on the para-athlete community for training and monitoring methods being immense, much more research is needed to refine these approaches into adaptive athlete monitoring.
REFERENCES


CHAPTER 4
COMPARISON OF BARBELL VELOCITIES FOR PARA POWERLIFTING SECURED VS UNSECURED

ABSTRACT

Purpose: Paralympic powerlifting is a contest for adaptive athletes to compete in the bench press event. These competitions are primarily sanctioned by the International Paralympic Committee (IPC) and its affiliates. Specialized bench press tables are used in IPC competitions that enable athletes’ easy access to the bench press surface as well as accompanying Velcro straps that secure the lifter in place for stability and safety. The purpose of this study is to examine the advantages or disadvantages of being secured to the bench in the same fashion that is used in IPC competition in safety as well as training adaptations. Methods: This was a single subject observational design to retrospectively find a measurable difference in velocities secured vs. unsecured during the bench press exercise in the training for para-powerlifting competition. The measures were taken over the course of a 10 week period. Each week alternated the order of the 2 sets of 3 reps in each condition. The first 4 weeks and latter 4 weeks were inverted in order to test under each relative intensity in training equally. Average of daily Secured and Unsecured Peak and Mean velocities compared for each session. Order of conditions alternated each week of the initial 4 week block and inverted for the next 4 week block. Results: ICC values reported show moderate to very good intraclass correlations within the samples. Coefficients of variation are approaching 10%. Increased stability from being secured by a strap following the IPC protocol for competition allows the subject to consistently create substantially higher velocities. Conclusions: Para-powerlifters and para-athletes training for upper body power development should likely perform benchpress using a strap to secure them to the bench for enhanced

55
stability. The significant and consistently increased force outputs the added stability enables the athlete to utilize may bring more significant training adaptations towards their goals.

INTRODUCTION

Paralympic athletes (PA) tend to face chronic overuse injuries from daily wheelchair or crutch use. Over 50% of these injuries are shoulder related and impact daily life for these athletes (Ferrara, 1992). Adaptive powerlifters (AP) are a subdivision of Paralympic athletes and are at high risk for catastrophic injuries due to fatigue and lifting maximal weights. It is vital to have well-designed and adaptive training plans for these athletes to preserve quality of life and maximize performance in competition. Unfortunately, there is a lack of literature on training adaptive athletes for performance.

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Velocity measurements have been shown to predict 1RM through the load-velocity relationship. Previous studies have suggested that movement velocity can help predict the relative load of both upper and lower body resistance exercises (García-Ramos 2017). Creating a
load-velocity profile for athletes can help coaches track an athlete over time and their progress. Load-velocity may also be used to estimate daily readiness without interfering with the prescribed load of the training session. Monitoring repetition velocity may estimate the stress induced by resistance training (8), and may be an indicator of fatigue during that exercise or training session.

PUSH (PUSH Inc, Canada) is an inertia sensor that is specifically designed to be used during resistance training. The device can be worn on the arm and can provide the coach or athlete an estimation of the movement of the barbell that is gripped with the hands. The device provides average and peak values for velocity and power on the app provided by PUSH which can be used via smartphone or tablet. A Study conducted by Sato et. al (2015) showed that the inertia sensor in the PUSH device is accurate when compared to a 3D motion capture system, but it should be noted that the study only looked at dumbbell exercises.

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<td>3 Ripley &amp; McMahon</td>
<td>2016</td>
<td>NSCA NetCon</td>
<td>BB Jump Squat</td>
<td>Force Plate</td>
<td>V 3.0.1</td>
</tr>
<tr>
<td>5 McGloth et al.</td>
<td>2018</td>
<td>J. Aust. Strength Cond.</td>
<td>BB Bench Press</td>
<td>3D Motion Capture</td>
<td>N/A</td>
</tr>
<tr>
<td>6 Orange et al.</td>
<td>2018</td>
<td>J. Strength Cond. Res.</td>
<td>BB Back Squat</td>
<td>Linear Position Transducer</td>
<td>V 3.0.1</td>
</tr>
<tr>
<td>7 Wee et al.</td>
<td>2019</td>
<td>Sport Perf. Sci. Review</td>
<td>Countermovement Jump</td>
<td>Force Plate</td>
<td>V 4.2.0</td>
</tr>
<tr>
<td>8 Perez-Castilla et al.</td>
<td>2019</td>
<td>J. Strength Cond. Res.</td>
<td>Smith Machine Bench Press</td>
<td>3D Motion Capture</td>
<td>V 3.0.1</td>
</tr>
</tbody>
</table>

Eight other studies have examined the validity and reliability of the PUSH device. One study investigated movement velocity during the back squat and found that the PUSH device showed high correlations with mean ($r=0.85$), and peak velocity ($r=0.91$) when compared with a
T-Force linear transducer (Balsalobre-Fernandez, C., Kuzbub, M., Poveda-Ortiz, P., Campo-Vecino, J., 2016). Ripley and McMahon (2016) looked at the PUSH device compared to force plates when testing countermovement jumps. Within-session reliability was found for peak velocity and peak power for both the force plates and the PUSH device but the PUSH device overestimated all values compared to the force plates. Therefore, correction equations were produced.

The bench press has been used to explore the load and velocity relationship (González-Badillo 2010; Jidovtseff, B. 2011) and has been widely explored (Bazuelo-Ruiz, B. 2015). The load-velocity of multi-joint exercises have been found to be highly linear (Munoz-Lopez, 2017). In one study, the mean velocity was shown to have the highest linearity of the load-velocity relationship and may be thought to be a more accurate measure for monitoring relative load (Garcia-Ramos 2018).

A study conducted by Gonzalez-Radillo and Sanchez_medina (2010) investigated mean velocity and relative load and found that when it was attained with a given absolute load it can be an accurate estimate of the relative load (1RM) (Cronin 2003). Therefore, it can be a practical way to monitor training load during resistance training.

METHODS

Study Design

This was a single subject observational design to retrospectively find a measurable difference in velocities secured vs. unsecured during the bench press exercise in the training for para-powerlifting competition. The measures were taken over the course of a 2-month period. Training was conducted 3 times a week consisting of a Heavy Push day, Heavy Pull day and a
Light Push Day (repeated effort from Heavy Push with weights decreased 15%). Exercise selection was primarily compound exercises separated by push and pull movements on separate training days. Each week alternated the order of the 2 sets of 3 reps in each condition. The first 4 weeks and latter 4 weeks were inverted in order to test under each relative intensity in training equally. Average of daily Secured and Unsecured Peak and Mean velocities compared for each session. Order of conditions alternated each week of the initial 4 week block and inverted for the next 4 week block.

Subject Profile

The subject observed in this case study was a 34-year-old male 5’2” in height and weighing between 73 and 82 kg. His training experience included 10 years of intermittent resistance training with the previous two years being consistently regimented. Competition experience was 3 local bench press competitions along with 2 national level para-powerlifting meets sanctioned by the IPC. Bench press displacement was measured 47 cm throughout the training process. The heaviest bench press achieved in competition was 130 kg at a weight of 73.9 kg. Informed consent form was signed by the subject and approved by the IRB.

Training design

Training design was broken down into 2 mesocycles or “blocks” (4 weeks of the same exercises with waved relative intensities) and microcycles (1 week of training). The primary exercise sets and reps per block were: (4 weeks) Block: 1 3 sets of 5 reps, (2 weeks) Block: 2: 4 sets of 15 reps, (4 weeks) Block 3: 3 sets of 10 reps, Microcycles in the block normally waved in relative intensity (Relative Intensity Load= Weekly Training Load/Peak Intensity Week Load in the same block) from: Week 1 65%, Week 2 85%, Week 3 95%, (Peak Intensity) Week 4 100%.
Warm Up Procedures

The common warm up protocol for all training days included grip dynamometer testing, seated shoulder circles with a 2 ½ kg plate 10 reps per side and dumbbell rows with 50 pounds and reps per side. Bench press specific warm-ups before velocity testing included 20 kg, 40 kg, and 60 kg for 10 reps with 1-2 minutes rest followed by 80 kg for 5 reps with 2 minutes rest.

Collection Procedures

Bench Press barbell velocity testing emulated the exact technique used in IPC competition from the rulebook (IPC, 2012). A total of four sets of three reps were done with 100 kg on bench press while wearing the PUSH accelerometer unit around the middle of the forearm. The control condition was performing to sets of three reps without being secured to the bench laying uninhibited. The experimental condition used was using leather strap to secure the subject down on two of the four sets across the mid thigh to the bench to simulate competition conditions as well as possible. Each week alternated the order of the 2 sets of 3 reps in each condition. The first 4 weeks and latter 4 weeks were inverted in order to test under each relative intensity in training equally. Average of daily Secured and Unsecured Peak and Mean velocities compared for each session. Order of conditions alternated each week of the initial 4 week block and inverted for the next 4 week block. The PUSH accelerometer unit was placed at the midline of the left forearm for all tests. Peak and mean velocities from each rep were collected and displayed on the PUSH application and recorded into Microsoft Excel.

Statistical Analysis

ICC and coefficient of variance measures were made for secured and unsecured tests of peak and mean velocities. Cohen’s D effect sizes were performed to show changes between measures under different conditions in the context of standard deviations. As an exploratory
study, no baseline corrections were needed to counter type I errors. All data was recorded between December 2017 and February 2018. All statistics were performed on Microsoft Excel 2016 (Microsoft, Redmond, WA, version 16.0.11727.20188).

RESULTS

ICC values reported in Table 1 shows moderate to very good intraclass correlations within the samples. Coefficients of variation are all approaching 10%. Means and standard deviations are also listed here. Cohen’s D effect size measures are shown in Table 2. Figures 1 and 2 give visual depictions of the separation between the two conditions in velocities over the course of the study.

Table 4. 2 shows reliability stats pertaining to the bench press velocities reported over the 10-week data collection period.

<table>
<thead>
<tr>
<th>Reliability Measures</th>
<th>ICC</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsecured Avg Peak Vel</td>
<td>0.78</td>
<td>11.02%</td>
</tr>
<tr>
<td>Unsecured Avg Mean Vel</td>
<td>0.87</td>
<td>10.48%</td>
</tr>
<tr>
<td>Secured Avg Peak Vel</td>
<td>0.67</td>
<td>9.74%</td>
</tr>
<tr>
<td>Secured Avg Mean Vel</td>
<td>0.57</td>
<td>10.63%</td>
</tr>
</tbody>
</table>

Table 4. 3 shows the Cohen’s D effect sizes comparing Unsecured vs. Secured Peak and Mean velocities.

<table>
<thead>
<tr>
<th>Effect Size Measures</th>
<th>Mean (m/s)</th>
<th>SD</th>
<th>Cohen’s D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsecured Peak Velocity</td>
<td>0.3423</td>
<td>0.053383</td>
<td>-0.75</td>
</tr>
<tr>
<td>Secured Peak Velocity</td>
<td>0.3845</td>
<td>0.05872</td>
<td>0.75</td>
</tr>
<tr>
<td>Unsecured Mean Velocity</td>
<td>0.2205</td>
<td>0.05872</td>
<td>-0.77</td>
</tr>
<tr>
<td>Secured Mean Velocity</td>
<td>0.2567</td>
<td>0.03168</td>
<td>0.77</td>
</tr>
</tbody>
</table>
Figure 4.1 graph contrasting the visual differences between the peak velocities of the athlete when they are secured to the bench and unsecured.

Figure 4.2 graph contrasting the visual differences between the mean velocities of the athlete when they are secured to the bench and unsecured.
DISCUSSION

ICC and CV calculations show strong reason to believe the data is reliable in this study. The Cohen’s D show an effect size approaching strong differences in favor of higher velocities on bench press for the subject when secured and stable on the bench. It appears evident the increased stability from being secured by a strap following the IPC protocol for competition allows the subject to consistently create substantially higher velocities. We do know from a large amount of research that stability is a prerequisite for reducing force resistance training. Koshida et al found this specifically with bench press (Koshida, 2008). Maximum force creates higher muscle activations and stimulates better adaptations than conditions that inhibit maximum force production like unstable environments (Bruhn, 2004) (McBride, 2006) (Behm, 2002). Training in this sub optimal fashion chronically can actually cause regression in training lack of significant stimulus (Drinkwater, 2007). Training in unstable conditions can sometimes increase change of injury as well from involution of strength (Verhagen, 2007). For para-powerlifters and para-athletes that wish to improve their dynamic strength, stability will likely be a must for optimal training adaptations (Davies, 2017).

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REFERENCES


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