The Influence of Velocity-Based Resistance Training on Strength and Power Development

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Abstract

Sports that require high levels of strength and power typically employ traditional percentage-based training methods (%1RM). However, a major flaw to this form of training is that it does not take into account the athletes daily biological status and readiness to train. Therefore, movement velocity has been proposed as a viable method of resistance training to enhance performance. The purpose of this thesis was firstly, to examine literature on the adaptations and current practices of traditional based training (TT, %1RM) and velocity-based training methods (VBT). Secondly, to investigate the reliability of the bar mode application (band attached to the bar) of the PUSH band accelerometer in measuring peak velocity (PV) during the barbell squat jump exercises (SJ), and finally, to investigate the effects of VBT training on neuromuscular strength (back squat [BS], bench press, [BP]) and power (squat jump PV using the PUSH band) in comparison to TT (%1RM). The PUSH band showed *high* to *perfect* reliability in PV_{max} and PV_{mean} across four trials (mean ICC 0.91 & 0.90). The results are in agreement with previous research conducted on the PUSH band accelerometer (when attached to the subjects forearm). No significant differences were found between groups in strength and power measures ($p > 0.05$). Furthermore, between-group effect sizes were deemed *trivial* for BS and BP ($d = 0.00$ and 0.03, respectively), while the effects for PV_{max} ($d = 0.23 \pm 0.73$) and PV_{mean} ($d = -0.38 \pm 0.59$) were deemed *unclear.* Future research should focus on assessing the reliability of the bar mode application on other traditional exercises (BP, BS, deadlifts) at various intensities (20 – 90%1RM). Additionally, future research should utilise a larger sample size and a more homogenous strength/training group in order to determine any potential effects.

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List of Abbreviations

1RM	The heaviest load a muscle or group of muscles can lift
%1RM	Percentage of 1RM
AF	Augmented Feedback
BP	Bench Press
BS	Back Squat
CV	Coefficient of Variation
ES	Effect Size
FP	Force Platform
FB	Feedback
HJ	Horizontal Jump
halfV	Half concentric velocity
ICC	Intraclass correlation coefficient
LE	Level of Effort
LPT	Linear Position Transducer
maxV	Maximal Concentric Velocity
MF	Mean Force
MP	Mean Power
MV	Mean Velocity
$m.s^{-1}$	Meters per second
NFB	Non-Feedback
PC	Power Clean
PF	Peak Force
PO	Power Output
PPO	Peak Power Output
PP	Peak Power
PV	Peak Velocity
PV_{max}	Highest peak velocity achieved
PV_{mean}	Average peak velocity achieved over two sets

RM	:	Repetition Maximum
SD	:	Standard Deviation
SJ	:	Squat Jump
sRPE	:	Session Ratings of Perceived Exertion
TT	:	Traditional Training group
VBT	:	Velocity-Based Training
VC	:	Velocity Cut-off
VL	:	Velocity Loss
VJ	:	Vertical Jump

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Thesis Overview

The current thesis is comprised of four chapters. The experimental chapters are written as complete articles so there may be some repetition of information (all references will be in one section). Chapter one contains a review of literature and introduces the reader to traditional based training and velocity-based training methods. Chapter two investigates the reliability of the PUSH band 2.0 in measuring peak velocity during the barbell squat jump exercise. Chapter three focuses on an original investigation comparing the effects of percentage based training methods (%1RM) to velocity-based training methods in strength and power development (using the PUSH band). Lastly, chapter four provides future research recommendations.

Chapter One:
Literature Review

Traditional Based Training Methods

Strength Adaptations

Strength defined

Strength is defined as the maximum amount of force produced by a muscle or muscles at any given speed (Baker & Nance, 1999) and can be either dynamic or isometric (McMaster, Gill, Cronin & McGuigan, 2014; Tan, 1999). Maximal strength is typically assessed using a one repetition maximum (1RM); the heaviest load a muscle or group of muscles can lift (Carpinelli, 2011; Tan, 1999).

Acute and chronic physiological and hormonal adaptations to strength training

Maximal strength improvements can be attributed to specific neural, morphological, and hormonal adaptations. Initially, acute responses to maximal strength training are due to neural adaptations such as increased firing frequency, motor unit recruitment and synchronisation, intramuscular and intermuscular coordination and rate coding (Folland & Williams, 2007; Zatsiorsky & Kraemer, 1995). Chronic adaptations to maximal strength gradually change from neural to morphological contributions. Increases in cross-sectional area of the whole muscle and individual muscle fibres, alterations of muscle fibre types (Types IIb to IIAB to IIA) and myofibrillar growth and proliferation are examples of chronic adaptations (Folland & William, 2007; Fry, 2004; Hakkinen et al., 2003; Tillin & Folland, 2014; Zatsiorsky & Kraemer, 1995).

The endocrine system plays an essential role in strength development. Resistance training improves muscle protein turnover by modifying the anabolic (e.g. testosterone, human growth hormone) and catabolic (e.g. cortisol) responses to training (Crewther, Keogh, Cronin, & Cook, 2006). The anabolic and catabolic responses are crucial for the development of acute and chronic adaptations to strength training. For example, secretion of testosterone for muscle growth occurs by increasing protein synthesis and decreasing protein degradation (Crewther et al., 2006; Smilios, Tsoukos, Zafeiridis, Spassis, & Tokmakidis, 2013). Furthermore, testosterone may play a significant role in the development of force and power production (Crewther et al., 2006; Kraemer & Ratamess, 2005). Indeed, the magnitude of elevation of the catabolic and anabolic hormones, has been shown to be influenced by variables such as, exercise selection, intensity, volume, nutritional intake, velocity of contraction, training experience, and is independent of the athletes training level (Crewther et al., 2006; Kraemer & Ratamess, 2005; Kraemer et al., 1999; Smilios et al., 2013).

The effects of strength training history on adaptations

The status of the athletes training level may also affect strength adaptations (Baker, 2001a). As an athlete reaches a high level of strength development, it becomes difficult for them to continue to improve. Ahtianen, Pakarinen, Alen, Kraemer and Kakkinen (2003), investigated the magnitude of strength development over a 21-week period in strength-trained and untrained men. Results indicated that the untrained group increased maximal force production (20.9%) significantly more compared to the strength-trained group (3.9%). This suggests that well-trained strength athletes need to find alternative ways to adapt their training to continually increase strength. Suggested loads >80% of 1RM are crucial to maximising strength gains for well-trained athletes (Campos et al., 2002). The heavy load results in lower contractile velocities ensuing more time under tension and therefore an enhancement of strength and hypertrophic adaptations (Tillin & Folland, 2014).

Structuring resistance training variables

When designing resistance training programs, practitioners typically manipulate specific variables to enhancing strength (e.g. sets, repetitions, load, movement velocity, frequency, type, rest, the percentage of 1RM, order of exercise [Tan, 1999]). Structuring training programmes for athletes can involve the manipulation of different cycles, starting with macro-cycles (months/years) which contain multiple meso-cycles (training weeks) which further divides into micro-cycles (training week/days) (Fleck, 1999; Issurin, 2010). Suggested dosage for the increase in strength consist of 3-5 sessions a week, covering 3-6 sets of 2-6 repetitions, training at an intensity >80% of an athletes 1RM, with recovery of 3-5min between sets (Fisher, Steele, Bruce-Low & Smith, 2011; McMaster et al., 2014; Peterson, Rhea, & Alvar, 2005; Tan, 1999). The manipulation of these training variables within the different training cycles will enable a strength and conditioning practitioner to properly optimise maximal strength gains in their athletes over acute and chronic periods of time.

Current practices for determining intensity for traditional strength training

Manipulation of intensity is considered to be of great importance when enhancing strength (Fry, 2004; Tan, 1999). Traditionally, intensity is associated with the percentage of either 1RM or estimated 1RM that is lifted (Fisher et al., 2011; Peterson et al., 2005). The benefits of utilising percentage of 1RM (%1RM) are due to the ability to effortlessly individualise athlete's training loads for a pre-selected training intensity. However, there are flaws in this method. Performing a maximal strength test (1RM) or submaximal test (3-10RM) can be problematic and impractical. Maximal strength testing can be a time-consuming process, unrealistic for large training groups and can cause injury (Gonzalez-Badillo, Marques, & Sanchez-Medina, 2011). Furthermore, the acquired 1RM value does not account for day to day fluctuations in physiology state, physical performance and life stressors (Mann, Ivey, & Sayers, 2015). Indeed, the day to day fluctuations may dramatically affect what the athlete can lift in a session, that is, the %1RM lifted could be too heavy or too light for that particular session (Gonzalez-Badillo, Sanchez-Medina, Parejo-Blanco, & Rodrigues-Rosell, 2017a).

Alternatively, loading intensity can be determined through trial and error. This involves performing a maximum number of repetitions within a given submaximal weight (Gonzalez-Badillo et al., 2011; Gonzalez-Badillo & Sanchez-Medina, 2010). For example, ten repetition maximum (RM) is a weight lifted ten times, but no more. Scholars have identified a relationship between the number of repetitions to failure and the %1RM (Brzycki, 1993; Reynolds, Gordon, & Robergs, 2006; Wood, Maddalozzo, & Harter, 2002). Although RM testing eliminates the need for a direct 1RM assessment, it is not without its drawbacks. Due to the higher number of repetitions associated with RM testing (3-10RM), increases in fatigue and metabolic strain occurs. From a practical perspective, the first set of repetitions to failure will result in the subsequent sets being reduced, regardless of recovery (Gonzalez-Badillo & Sanchez-Medina, 2010). Moreover, increasing evidence shows that training to failure does not necessarily improve strength and is counterproductive to force production, velocity and the nervous systems ability to activate the muscles during contraction. This is due to excessive fatigue, mechanical and metabolic strain, and the undesirable transition to slow twitch fibre types (Davis, Orr, Halaki, & Hackett, 2016; Folland, Irish, Roberts, Tarr, & Jones, 2002; Gonzalez-Badillo & Sanchez-Medina, 2010; Marques, 2017; Sampson & Groeller, 2015).

More recently, ratings of perceived exertion within a session (sRPE) allows athletes to adjust load based on their perception of training load (Banyard, Tufano, Delgado, Thompson, & Nosaka, 2018). sRPE was intended for aerobic and anaerobic exercise; however, sRPE has become an alternative to percentage-based resistance training as it is easy to administer. The validity and reliability of sRPE use within resistance training is well documented (Helm et al., 2016; McGuigan & Foster, 2004). Though, this form of training can be problematic due to its subjective nature and the requirement of a prescribed number of repetitions within a set to be completed before adjustments of load can be made, resulting in an increased level of fatigue and potential decrease in strength enhancement (Banyard et al., 2018). Scholars have identified the need for an alternative means for the assessment and prescription of intensity within resistance training. Movement velocity is one method in which scholars and practitioners have identified as a viable means for strength and power assessment and training.

Summary of strength

In summary, percentage-based training and sRPE has been proven to be a practical means of improving maximal strength. However, contention within the literature exists as to whether these methods are the most effective and efficient methods of prescription. The athletes training level is a key aspect to consider when designing resistance training programs as it has been proven that those with a higher training age have limited potential to improve further. Additionally, adapting specific resistance variables such as training volume (sets x reps x load) and velocity of contraction could provide an alternative stimulus to encourage neural, morphological or hormonal adaptations associated with the improvement of maximal strength.

Power Adaptations

Defining power and its importance to sporting performance

Maximal power describes the highest level of power (work/time) achieved in a muscular contraction (Cormie, McGuigan & Newton 2011a). Furthermore, Cormie and colleagues (2011a) have suggested that maximal power represents the highest instantaneous power during a single movement performed with the goal of producing maximal velocity at take-off, release or impact. Indeed, mechanical power can be defined as the rate of doing work and is calculated by multiplying the force by the velocity of movement (Haff & Nimphius, 2012). The calculation is as follows.

Power = work/time
    = force x distance/time
    = force x velocity

Based on this equation, it is evident that there are two main components to producing mechanical power; there is the ability to apply high levels of force, and expressing high contractile velocity (Haff & Nimphius, 2012; Kraemer & Looney, 2012). Power output generating capabilities are among the most critical factors in sports performance, especially those sports that involve jumping and sprinting (Haff and Potteiger, 2001). This is supported by multiple studies which indicate significant power outputs achieved by their athletes who perform at a high level of their chosen sport (Baker 2001a; Baker 2001b).

The significance of strength for power development

Strength is considered one of the foundational elements required for the development of power (Haff & Nimphius 2012). A fundamental relationship between strength and power exist, which dictates that an individual cannot possess a high level of power without first being relatively strong (Cormie et al., 2011b). Essentially, stronger athletes can generate force faster than their weaker counterparts (Haff & Nimphius, 2012). This is confirmed by Baker and Nance (1999) in which they investigated the relationship between strength and power in professional rugby league players. Their results showed a significant relationship between 3RM bench press and incline bench throw (r = 0.89) and 3RM back squat and hang power clean (r = 0.79). Furthermore, multiple scholars have found in their respective studies that athletes who have higher strength levels will produce higher amounts of power output when compared to groups with lower strength levels (Cormie, McCaulley & McBride, 2007a; Cormie, McGuigan & Newton 2010a; Cormie, McGuigan & Newton 2010b; Young, McLean & Ardagna, 1995; Young, 2006).

The effects of using low vs. high load on power output

The intensity in which optimal power is achieved is a topic of interest for many researchers (Baker, 2001b; Bevan et al., 2010; Cormie et al., 2007a; Thomas et al., 2007; Wilson, Newton, Murphy & Humphries, 1993). General dosage guidelines for power training can range from 3-5 sets of 3-6 repetitions, at intensities below 60% of 1RM (Bevan et al., 2010; Kawamori & Haff, 2004; Thomas et al., 2007; Wilson et al., 1993). Thomas and colleagues (2007) investigated the effects of a variety of resistance intensities (30-70% of 1RM) on maximal power output for the squat jump (SJ) on male and female athletes. It was reported in this study that athletes of both genders saw significant improvements in power output at 30-50% of 1RM. This is consistent with Bevan and colleagues (2010), who found peak power output (PPO) was significantly higher in the ballistic bench press (BBP) at 30% of 1RM and 0% (bodyweight) for the SJ in their respective study. This further solidifies the notion that power output is achieved utilising intensities below 60% of an athletes 1RM (Cormie et al., 2011b; Cormie et al., 2010a; Cormie et al., 2007a; Cormie et al., 2007b; Kawamori & Haff, 2004; McBride, Triplett-McBride, Davie, & Newton, 2002; Zemkova et al., 2014).

Conversely, research that suggests higher loads (70-90% of 1RM) can also elicit increases in PPO (Kawamori & Haff, 2004; Cormie et al., 2007a). Cormie et al., (2007a) found that absolute and relative PPO was significant at 80% of 1RM for the power clean (PC). It has been suggested that optimal loading for maximising PPO in Olympic style weightlifting exercises appear to be higher compared with traditional resistance exercises (Kawamori & Haff, 2004). This is in agreement with Cormie and colleagues (2007b), who reported that the optimal load for the PC was 80% of 1RM, further hardening the notion that Olympic style lifts require higher submaximal loads (> 80% of 1RM). This is consistent with other research that showed improvements in power were achieved using higher loads (McBride et al., 2002; Harris, Cronin, Hopkins & Hansen, 2008).

The adaptations associated with higher loads can be due to the size principle, which suggests using heavy loads to fully recruit and fully train fast twitch motor units with high thresholds (Kawamori & Haff, 2004). Fast twitch motor units produce more PO than slow twitch motor units. In contrast, lighter loads (< 60% of 1RM) stimulate neural factors such as increased firing frequency, motor unit synchronization intermuscular coordination and rate of force development (RFD) due to the increased velocity achieved at these intensities (Cormie et al., 2011a; Kawamori & Haff, 2004; Kramer & Looney, 2012).

The use of different modalities for the development of power

Practitioners have utilised different modalities to enhance PO. They are ballistic, plyometric and Olympic style exercises. These exercises allow acceleration through the entire range of motion, and in some cases, to the point of projection. Concentric velocity, force, power, RFD and muscle activation are higher as a result, compared to traditional resistance exercises (Cormie et al., 2011b).

Additionally, the rationale behind the use of traditional exercise to develop power is questioned within the literature (Newton, Kraemer, Hakkinen, Humphries, & Murphy, 1996). This is due to the magnitude of load applied to the exercise, which can result in a substantial portion of the movement involving a period of deceleration at the end of the concentric portion of the lift (Newton et al., 1996; Newton & Kraemer, 1994; Sanchez-Medina, Perez & Gonzalez-Badillo, 2010). This will affect factors such as neural and muscle activation, and recruitment of fast twitch muscle fibres (Newton & Kraemer, 1994; Newton et al., 1996). This confirms the need for the implementation of these modalities mentioned above to provide an alternative means of producing PO.

Summary of power training

Collectively, maximal power development is a critical component for sports performance and is said to be affected by an athlete's strength status and exercise selection. The research has shown that PPO can be achieved at both low (0 - 65% of 1RM) and high (> 80% of 1RM) intensities. The improved PO can increase firing frequency, motor unit synchronisation, intermuscular co-ordination, and fibre type composition. However, the intensity needed to maximise PO is both conflicting and provides confusion as to what is the optimal loading parameters to increase PO. Therefore, when implementing power-based exercises into an athlete's resistance training regime, one could consider the actual velocity of the movement as a parameter to determine loading and optimise PO.

Velocity Based-Training Methods

History of velocity-based training

Velocity-based training (VBT) is a concept that has been of great interest to strength and conditioning practitioners. This involves the prescription of velocity targets rather than %1RM targets (Mann et al., 2015). Historically, VBT has been conducted on isokinetic equipment (Behm & Sale, 1993; Pereira & Gomes, 2003). However, this form of training has shown to be far less specific and somewhat problematic to sporting movements that involve acceleration and deceleration (Kawamori & Newton, 2006). For these reasons, this has led to the development of technology (e.g. force platforms, linear position transducers, accelerometers) to be used for isoinertial resistance training, which has more of a carryover-effect to sporting performance (Kawamori & Newton, 2006).

VBT is an objective and practical method of prescribing both the intensity and volume to resistance training programs (Perez-Castilla, Garcia-Ramos, Padial, Morales-Artacho, & Feriche, 2018). These two variables are typically established using a 1RM and subsequent percentages of 1RM. However, strength testing and percentage-based training have certain drawbacks. VBT is considered a form of "Autoregulation" whereby the load is adjusted based on the day to day fluctuations in the individual's ability to move load (Mann, Thyfault, Ivey, & Sayers, 2010). This allows athletes to adjust the weight lifted at their own pace by catering the programme to the athlete's strength or performance for a given day (Mann et al., 2010). Specific velocity targets are established every session, and if the targets are not meet, then adjustment of load is carried out.

Technology associated with Velocity-Based Training

Brief history of measuring velocity, force and power

The use of technology in the sports industry is growing in popularity (Sato, et al., 2015). Specifically, force plate (FP) technology, Linear position transducers (LPT) and Accelerometers used together or separately, are examples of technology being used to measure velocity, force and power (Sato, et al., 2015). The use of this technology has enabled immediate feedback within sessions resulting in increased level of effort (LE), motivation, competitiveness and specificity of training. Variables such as mean and peak velocity (MV, PV), power (MP, PP), and force (MF, PF) are typically relayed back to the device used to aid in performance monitoring (Garcia-Ramos, Haff, Padial, & Feriche, 2018a; Garcia-Ramos, Pestana-Melero, Perez-Castilla, Rojas, & Haff, 2018b). However before this technology is used in training, the validity and reliability must be established. Historically, the measuring of force and velocity required the use of an FP in a laboratory setting. FP were considered the "gold standard" in force measurements (Cronin, Hing, & McNair, 2004). However, this technology has its drawbacks. The lack of portability and costly nature of the FP resulted in the development of new, portable, cost-effective devices, such as LPT and accelerometers that allow kinematic and kinetic information to be gathered similarly to an FP and used outside of a laboratory (Balsalobre-Fernandez, Kuzub, Poveda-Ortiz, & Campo-Vecino, 2016; Crewther et al., 2011; Cronin et al., 2004; Garcia-Ramos et al., 2018; Hansen, Cronin & Newton, 2011; Harris, Cronin, Taylor, Boris, & Sheppard, 2010; O'Donnell et al., 2018).

Linear position transducers

Linear position transducers have been validated and proven reliable when compared to the gold standard FP, so much so that similar forms of technology (Accelerometer devices) measure reliability and validity against an LPT device (Balsalobre-Fernandez et al., 2016). Specifically, LPT use a tethered cord (attached to a person or equipment) to extract time displacement data, and from this, movement velocity and estimates of force and power can be calculated (when load lifted, or subject's mass are factored in) (Crewther et al., 2011; Harris et al., 2010). Cronin et al., (2004) examined the validity and reliability of LPT when measuring MF and PF variables compared to an FP. The results showed an interclass correlation coefficient (ICC) of 0.92-0.98 for MF, 0.97-0.98 for PF and a coefficient of variation (CV) of 2.1-4.5% for MF and 2.5-84% for PF, respectively. Authors concluded the results indicate LPT to be a reliable and valid means of technology when compared to the FP. O'Donnell and colleagues (2018) found comparable results. Jump height, PV and MV were measured. Results indicated an ICC of 0.7 for jump height, 0.9 for PV and 0.91 for MV when compared to a FP. These results are further reinforced by scholars who completed comparable research (Crewther et al., 2011; Gomez-Piriz, Sanchez, Manrique, & Gonzalez, 2013; Hansen et al., 2011). Although the advantages of LPTs are similar to that of an FP, without the drawbacks (cost, portability), to some it can still be considered too expensive (Balsalobre-Fernandez et al., 2017). Thus, the need for cheaper, portable pieces of technology is warranted.

Accelerometers

Accelerometers are becoming more readily available for use and are more cost-effective than LPT devices. Like LPT devices, accelerometers can attach to the bar directly or on the subject, (waist strap, forearm) and relay information from the device to a smartphone, tablet or computer wirelessly (Bluetooth), allowing for real-time data collection at the training site (Sato, Sands, & Stone, 2012). The validity and reliability of different accelerometers have been established (Casartelli, Muller & Maffiuletti, 2010; Crewther et al., 2011; Gomez-Piriz, Manrique & Gonzalez, 2013). More specifically, the PUSH band has seen much attention over the years. To date, there are seven research articles which have measured the validity of the PUSH band (Balsalobre-Fernandez et al., 2016; Banyard, Nosaka, Sato, & Haff, 2017; Lake et al., 2018; Montalvo et al., 2018; Orange et al., 2018; Ripley & McMahon, 2016; Sato et al., 2015) with only three concurrently assessing the reliability (Balsalobre-Fernandez et al., 2016; Ripley & McMahon, 2016; Orange et al., 2018).

Although some scholars have shown the PUSH band to be valid (Balsalobre-Fernandez et al., 2016; Ripley & McMahon, 2016), concerns exist regarding the over and underestimation of data from the PUSH device when compared with LPT or FP. For instance, Balsalobre-Fernandez et al., (2016) found MV overestimated by 12.5%. This is consistent with Lake and colleagues (2018), who found that the PUSH band overestimated PV (9-17%) and MV (24-27%) while underestimating PP and MP (40-45%) in the CMJ compared to a FP. Furthermore, Ripley and McMahon (2016) found significant differences in PV and PP when compared to a FP ($p < 0.001$). Based on these findings it was concluded that PUSH devices should not be used interchangeably with LPT and FP as to avoid differences of reported data (Balsalobre-Fernandez et al., 2016; Gomez-Piriz et al., 2013; Lake et al., 2018).

Though contention exist over the validity, the reliability of the PUSH band has been well established. For example, Balsalobre-Fernandez and colleagues (2016) found a high level of reliability in MV (ICC = 0.91) and PV (ICC = 0.94) in the smith-machine BS. Ripley and McMahon (2016) found similar results when assessing the reliability of the PUSH band for PV (ICC = 0.91) and PP (ICC = 0.93). It is important to note, that when assessing for the validity and reliability of the PUSH band, this was done so by attaching the device around the subjects forearm or a waist belt (as directed by the manufacturer). However, the new PUSH band 2.0 device can now be attached to the bar itself (bar mode). To date, no research has assessed the validity and reliability of the new bar mode application of the PUSH band device.

Consideration of Velocity-Based Training

The intention for maximal concentric contraction

The intention to concentrically move the external load as quickly as possible is an important aspect for VBT. The intention to move explosively was first coined by

Behm and Sale (1993). The findings suggested that regardless of actual movement velocity, it was the intent to execute a high velocity movement that resulted in high velocity-specific training effects (Cronin et al., 2002). Behm and Sale (1993) was one of the first to suggest the importance of maximal contraction within resistance training (Kawamori & Newton, 2006). With the development of the appropriate technology today, scholars have continued to use this concept in VBT which provides a strength and conditioning practitioner with a better gauge of the LE the athlete is achieving within a set, compared to traditional %RM training (Gonzalez-Badillo et al., 2011). Indicators of LE within VBT are the velocity of the first repetition (determines the real intensity of effort) and the loss of velocity over a set (the set is stopped once below a pre-determined percentage). It has been suggested that the LE can be expressed as a ratio between the repetitions performed in a set and what could have been performed (Gonzalez-Badillo et al., 2017a). For example, if a subject performed a set of 10 repetitions and is stopped at 6, then the LE would be six over 10: 6(10), that is, a set of 6 repetitions that we could lift ten times (failure). The limit of repetition velocity loss should be set beforehand depending on the exercise selection and the primary training goal being performed (Gonzalez et al., 2011; Pareja-Blanco et al., 2017a; Pareja-Blanco, Sanchez-Medina, Suarez-Arrones, & Gonzalez-Badillo, 2017b; Perez-Castilla, Garcia-Ramos, Padial, Morales-Artacho, Feriche, 2018). Both the velocity of the first repetition and the loss of velocity over a set are vital to an athlete's LE and can provide objective information for future sets and sessions (adjustment of load) (Gentil et al., 2018; Gonzalez-Badillo et al., 2017b; Moran-Navarro et al., 2018).

Augmented feedback

Presenting an external source of information to athletes, such as lifting velocity, is referred to as augmented feedback (AF) (Nagata, Doma, Yamashita, Hasegawa, & Mori, 2018). Advances in technology (FP, LPT, Accelerometers) now enable the direct measurement of kinetic (e.g. velocity) and kinematic (e.g. power) variables during certain resistance training exercises (Randell et al., 2011). Subsequently, obtaining information regarding lifting velocity during training is essential to monitor progress and provide appropriate AF for athletes and coaches alike (Nagata et al., 2018). Randell et al., (2011) confirms this with significant improvements in VJ and HJ performance between feedback (FB) (4.6% & 2.6%) and non-feedback

(NFB) (2.8% & 0.5%) groups after six weeks of training. Likewise, Argus and colleagues (2010) saw a small increase in average PP (1.8% ± 2.7%) and velocity over a set (1.3% ± 0.7%) in the FB group over two sessions in the BP throw.

Immediate feedback after every repetition can inform athletes of whether they have met the required velocity needed for the set. With this knowledge, this will encourage the athlete to improve velocity output further. Research has found that AF can have a significantly positive effect on an athlete's motivation and competitiveness within resistance training (Mann et al., 2018; Nagata et al., 2018). Weakley and colleagues (2017) found MV to be higher in the FB ($0.70 m.s^{-1}$ ± 0.04) compared to NFB group ($0.65 m.s^{-1}$ ± 0.05). Furthermore, perceived pre-post motivation and competitiveness was said to be almost certainly higher in the FB group (Weakley et al., 2017). It is suggested that the type of AF could influence performance variables. Nagata et al., (2018) investigated whether immediate (FB after every repetition), averaged (average FB after each set) or visual (a video recording of each repetition after each set) FB would be more beneficial over a four-week training period for loaded JS. Results indicate that receiving immediate feedback after every repetition performed was most effective in producing improvements in JS. The research has proven the importance of FB on performance measures in VBT. Given that the research has shown improvements in performance measure as a result of AF, it would seem plausible to utilise this within resistance training in order to provide significant potential for adaptations and training effects.

Specific velocity-based training zones

Velocity zones can maximise training specificity by optimising velocity and specific loads within training sessions (Mann et al., 2015). For example, to develop maximal strength, a MV of $0.3 – 0.75 m.s^{-1}$ is recommended, for Strength-Speed (moving a moderate load at a moderate velocity), then a MV of $0.75-1.0 m.s^{-1}$ is recommended, likewise, if the goal was speed-strength (moving a lighter load at a high velocity) then a MV of $1.0-1.5 m.s^{-1}$ would be used. It is important to note that these velocities zones were established explicitly for traditional based exercises (squat, bench press, and deadlifts). Velocity zones for Olympic and ballistic movements need to use PV as this is a more consistent measure for these power-based movements (Mann, 2013). Scholars have identified PV of $1.55-1.85 m.s^{-1}$ for the power clean, and 2.0-2.25m.s^{-1} for the snatch, while for Squat jumps (SJ) a PV range of 1.8-2.5m.s^{-1} was recommended (Mann, 2013; Mann et al., 2015; Baker, 2018). By training within the range of the various velocity zones, athletes can maximise specificity within their training to ensure specific transfer to sporting performance (Mann et al., 2015)

Rational behind velocity thresholds

The velocity loss (VL) incurred during a training set has been proposed as a criterion to decide when each set should be stopped (Perez-Castilla et al., 2018). Pareja-Blanco et al., (2017b) states that fatigue increase as the number of repetitions increase, and if the exercise is not stopped, then failure will eventually occur. Moreover, increasing evidence suggests that performing repetitions to failure may not necessarily improve the magnitude of force production (Sanchez-Medina & Gonzalez-Badillo, 2011). Folland and colleagues (2002) failed to find a statistically significant result in his research which aimed to establish whether fatigue was necessary for strength improvements. This is consistent with Izquierdo et al., (2009) who found performing repetitions to failure resulted in a greater loss in functional capacity (e.g. decrease in PO). The increase in fatigue as a result of performing repetitions to failure, limits not only a fibres capacity for maximal force generation but also the maximum velocity of shortening and a slowing of relaxation occurs which affects power output (Sanchez-Medina & Gonzalez-Badillo, 2011). As a result of the technology available, monitoring VL during a training set has been proposed as a criterion to decide when each set should be stopped (Perez-castilla et al., 2018).

Research into velocity cut-off

VBT can further enable us to observe neuromuscular fatigue during a session by monitoring the percentage of VL in real time, over a set. For example, if an athlete performed one set of back squats for 12 repetitions with a velocity cut-off (VC) of 20%, then the set ceases once the velocity dropped 20% of the first or best repetition (if the first repetition was 1.0m.s^{-1} then it would be stopped at 0.8m.s^{-1}). Research has shown that implementing VC can significantly improve strength and power, despite potentially performing fewer repetitions than what has been prescribed (Pareja-Blanco et al., 2017a; Pareja-Blanco et al., 2017b; Perez-Castilla et al., 2018;

Sanchez-Medina & Gonzalez-Badillo, 2011). Pareja-Blanco et al., (2017b) investigated the effects of two resistance training programs differing only in VC (VL20% and VL40%) on functional (BS & CMJ) and muscle adaptation. The results showed the VL20 group had a similar improvement (despite performing 40% fewer repetitions) to the VL40 training group and a higher increase CMJ than the VL40 group (9.5% vs 3.5% $p < 0.05$). However, greater hypertrophy occurred in the VL40 group as a result of performing significantly more repetitions. Furthermore, Pareja et al., (2017a) investigated VL at 15% and 30% in professional soccer players ($n = 16$) over six weeks. Results indicate VL15% group significantly improved in strength performance (BS; $P < 0.01$) and CMJ ($p < 0.05$) compared to the VL30% group. Perez-Castilla and colleagues (2018) found BS strength improved more in the VL20% group compared to VL10%; however, CMJ was higher in the VL10% training group after four weeks of VBT.

Indeed, this shows that monitoring VL or VC in training allows for a more quality-based resistance training session, while also improving recovery time between sessions. Contention still exists as to the optimal percentage of VC for a specific training goal. Based on the research provided and recommendations from Baker (2018), one could suggest a VC of 5-10% for power development, 20-30% for strength and >40% for hypertrophy.

Velocity-based training on neuromuscular strength and power

The majority of research investigating the effects of VBT on strength and power typically use the BS, BP or a jumping movement (CMJ, SJ, drop jumps). Scholars have seen significant improvements in strength and power measures as a result of VBT. Torres-Torello et al., (2017) found significant improvements in squat strength after six weeks of VBT (17%). Gonzalez-Badillo and colleagues (2015) saw significant improvements ($p > 0.001$) in the load used to achieve $1 m.s^{-1}$ ($V1_{Load}$) in young soccer players of different ages (U16 & U18). Furthermore, Ramirez et al., (2015) found significant increases in absolute and relative power ($p < 0.001$) in the BS exercise after 10 weeks of velocity training. This is consistent with Hatfield et al., (2006) who saw significant improvements in peak power and peak force in the BS and shoulder press exercise at 60% and 80% or 1RM ($p < 0.05$). The aforementioned results have shown that monitoring velocity during training can significantly improve strength and power measures.

To the author's knowledge, no research that has directly compared the effects of VBT zones and percentage-based training methods. However, the research conducted by Gonzalez-Badillo, Rodrigues-Rosell, Sanchez-Medina, Gorotiaga and Pareja-Blanco, (2014) and Pareja-Blanco et al., (2014) are comparable. Gonzalez-Badillo and colleagues (2014) investigated the effects of maximal concentric velocity (maxV, n = 9) and half concentric velocity (halfV, n = 11) on BP strength over a six week intervention. Training volume was similar between groups (Set x reps x %1RM), however, the halfV group intentionally reduced concentric velocity (to correspond to half of intended velocity) whereas the maxV group performed maximal concentric velocity. Results indicate significant improvements in both training groups with maxV showing significantly higher percentage increase compared to halfV training group (18.2% vs. 9.7%). Pareja-Blanco et al., (2014) conducted similar research comparing maxV (n = 10) to halfV (n = 11) training and found similar enhancement in BS strength after six weeks of training (18% vs. 9.7%). Additionally, CMJ was also measured and found to be significantly higher in the maxV group compared to halfV group (8.9% vs. 2.4%). These studies reinforce the notion that the intent to move with maximal concentric velocity can result in significantly greater gains in strength and power than slower movement velocities.

More recently, a study conducted by Rauch and colleagues (2018) compared two different velocity based training zones on strength and power adaptations over a seven week period. One training group utilised a progressive velocity based training group, which increases the velocity by $0.05 m.s^{-1}$ over the course of the training intervention (PVBT, $0.55 – 1.0 m.s^{-1}$) and an optimal training load group, which maintains the same velocity for the training intervention (OTL, $0.85-0.9 m.s^{-1}$). The results indicated similar improvements in both training groups for BS and BP exercises as well as the deadlift ($p < 0.05$), with the OTL group showing greater increases in deadlift performance (22.9% vs. 10.9%).

The current research advocates that isoinertial VBT for the development of strength and power is a viable method of training. However, although studies have found improvements in strength and power, a lack of research exists with regards to specific VBT zones, and comparisons to percentage-based training methods. To date, only Rauch et al., (2018) has conducted research directly comparing velocity based training zones. The implementation of VBT zones, as stated by Mann et al., (2015), can further provide a more precise training focus (e.g., Maximal strength, Speed-strength, Strength-speed).

Velocity-based training effects on sports performance measures

One of the biggest advantages of utilising isoinertial resistance training is its apparent ability to transfer to sporting movements. As power is considered crucial for most sporting activities, the ability to transfer power improvements to sporting situations is paramount. Multiple scholars have seen strong relationships and improvements in performance parameters as a result of VBT. For example, Marques and colleagues (2007) found ball throwing velocity was strongly related to absolute bench press 1RM ($r = 0.637$), and peak bar velocity using 26kg ($r = 0.56$), and 36kg ($r = 0.63$). Furthermore, jump performance is crucial for many sports; hence many scholars have investigated and found VBT to be effective training method to improve jump ability (Gonzalez-Badillo et al., 2015; Negra et al., 2016; Pareja-Blanco et al., 2014; Torres-Torello et al., 2017). Gonzalez-Badillo and colleagues (2015) found significant improvements in CMJ in age group soccer players (U16 & U18) ($p = 0.000$). Additionally, Negra et al., (2016) found significant improvements in SJ (22%, $p < 0.001$) and standing long jump (15%, $p < 0.001$) after 12 weeks of low to moderate, high-velocity training. Scholar have found improvements in sprint performance with Loturco and colleagues (2015) showing significant improvements in 5m (8.2%), 10m (6.1%) and 20m (6.0%). Similar significant increase in 10m sprint time (7%) was found in Negra et al., (2016) own study. Results obtained from the above studies indicate that VBT can be an effective training method of improving performance measures, specifically throwing, jumping and sprint performance.

Conclusions

Collectively, it is clear that monitoring movement velocity within resistance training is an important variable to consider when designing and implementing resistance training programs. The current research suggest improvements in strength, power and performance measuring are evident as a result of VBT. In addition, research has shown that the intention to move explosively and the actual movement velocity achieved are both vital stimuli for the improvement in neuromuscular strength, power and performance (Behm & Sale, 1993; Kawamori & Newton, 2006). As a result of the technology available it is now possible to provide visual and audio feedback, which has shown to improve motivation and thereafter, performance (Randell et al., 2011; Nagata et al., 2018). Furthermore, with the implementation of VC, fatigue can be monitored while also presenting the athletes true LE.

Future research

Although improvements in strength and power have been shown with VBT, there is still a lack of research identifying specific velocity zones for a specific training goal (Maximal strength, Speed-strength, Strength-speed). Scholars have identified approximate zones to be used as a result of their own research and personal experiences (Baker, 2018; Mann et al., 2015; Rauch et al., 2018), however, the zones provided are conflicting. Clarification of this will enable a strength and conditioning practitioner to provide a more precise focus to their athletes training programs. Furthermore, future research should focus on other components such as specific agility or change of direction tests, and upper body performance measures in order to make a more convincing case to the belief that isoinertial resistance training can be transferable to sporting performance.

Chapter Two:

Study One: The reliability of the push band 2.0 accelerometer for measuring peak velocity during the barbell squat jump

Abstract

Objective: The present study aimed to investigate the reliability of the PUSH band 2.0 “bar mode” for measuring the barbell squat jump (SJ). **Methods:** A total of thirteen rowing participants (males: n = 8, age [mean ± SD], 20 ± 2 years; body mass, 86 ± 10 kg; height, 185 ± 10 cm; female: n = 5, age = 21 ±.0.5 years, body mass, 75 ± 6 kg, height, 178 ± 5 cm) volunteered for the present study. Participants performed two sets of three repetitions of the SJ exercise with three minutes rest between sets. The PUSH band accelerometer was connected to the end of an Olympic barbell and recorded peak velocity (PV) during the concentric phase of the SJ. The highest velocity achieved (PV_{max}), and the average of the two sets (PV_{mean}) was recorded for data analysis. This was completed over four session's separated by at least two days of rest. The intraclass correlation coefficient (ICC) and coefficient of variation (CV) were calculated to measure relative and absolute reliability. **Results:** No significant difference was found between trials one through four ($p > 0.05$). *Perfect* reliability (mean ICC) was found for PV_{max} (ICC = 0.91) and PV_{mean} (ICC = 0.90) while CV was found to be *moderate* for both PV_{max} and PV_{mean} (mean CV = 8.7% & 8.9%). **Conclusion:** The results of the current study show the bar mode application of the PUSH band 2.0 to be reliable for the SJ exercise.

Key Words: Power, Technology, Athlete monitoring

Introduction

The use of technology within the sporting industry to measure an athlete's physical status has grown exponentially (Sato et al., 2015). Force plate (FP) technology and linear position transducers (LPT) are considered the “gold standard” when obtaining kinetic and kinematic data. Nonetheless, due to the costly nature and lack of portability of this equipment, more practical and affordable means of technology, such as an accelerometer, have been developed to gather similar data, outside of a laboratory (Harris, Cronin, Taylor, & Boris, 2010; O’Donnell, Tavares, McMaster, Chambers, & Driller, 2018). An additional benefit of such technology is the ability to be used in a resistance training program to monitor velocity throughout the sessions.

The notion of using movement velocity to achieve specific performance goals within the gym has been gaining popularity in strength and conditioning facilities and within the literature (Gonzalez-Badillo, Marques, & Sanchez-Medina, 2011; Mann, Ivey, & Sayers, 2015). Furthermore, understanding the precision and reproducibility of the devices in question is vital as this will better a practitioner’s ability to quantify expressions of strength, power, assessment and understanding of the physiological determinants which in turn will guide programming to better effect (Harris, Cronin, Taylor, Boris, & Sheppard, 2010; Hopkins, 2015).

One device of particular interest is the PUSH band accelerometer. This device can be positioned on the subject’s forearm, waist belt and more recently, attached to an Olympic barbell directly, with information relayed via Bluetooth to an Apple IPad, iPhone or computer. To date, seven studies have investigated the validity of the PUSH band accelerometer (Balsalobre-Fernandez, Kuzdub, Poveda-Ortiz & Campo-Vecino, 2016; Banyard, Nosaka, Sato, & Haff, 2017; Lake et al., 2018; Montalvo et al., 2018; Orange et al., 2018; Ripley & McMahon, 2016; Sato et al., 2015), with three concurrently assessing the reliability (Balsalobre-Fernandez et al., 2016; Orange et al., 2018; Ripley & McMahon, 2016). Balsalobre-Fernandez and colleagues (2016) found a high level of agreement for mean velocity (MV, ICC = 0.90) and PV (ICC = 0.94) when using the back squat exercise. Furthermore, Ripley and McMahon (2016) also found a strong level of agreement in the PV (ICC = 0.91) and peak power (PP, ICC = 0.93) in the CMJ exercise. The majority of research assessing the reliability and validity of the PUSH band has done so by attaching the band to the subject's forearm (as per the manufactures directions) with one attaching to a waist belt (Lake et al., 2018). However, due to the development of the new PUSH band 2.0, the band can now be attached to a barbell (bar mode) allowing for quick and smooth transition from athlete to athlete.

To the author's knowledge, no study has measured the reliability of the PUSH band 2.0 accelerometer using the "bar mode" option for any exercise. If the accelerometer is to be used in this mode, it is vital that the reliability of this mode is assessed. Therefore, the purpose of this investigation is to assess the reliability of the PUSH band, using bar mode, in measuring PV in the SJ. Based on the current literature, it is hypothesised that the PUSH band will demonstrate high reliability in measuring SJ PV across four sessions.

Methodology

Participants

Thirteen rowers volunteered to take part in the study. Physical characteristics are displayed in Table 1. All participants were proficient at performing the SJ exercise and had no acute or chronic injuries. Before the beginning of the first session, the participants were informed of the risks and provided written informed consent. Participation was voluntary, and subjects had the option to withdraw at any time. Ethical approval was obtained through the University of Waikato Human Research Ethics Committee.

Table 1. Physical characteristics of the participants.

	Male (n = 8)	**Female (n = 5)**
Age (Years)	20 ± 2	21 ± 0.5
Weight (kg)	86 ± 10	75 ± 6
Height (cm)	185 ± 10	178 ± 5
Training Experience (Years)	4 ± 1	4 ± 1

Procedure

Participants began with a standard warm-up involving five minutes of cycling followed by mobility and dynamic stretches (Table 2). Two familiarisation sessions took place before the start of the first session of data collection to give participants an understanding of the movement requirements and the technology. The data collection occurred at the beginning of their regular weight training session. An outline of the training week for the athletes are detailed in Table 3. There was a total of four trials, each separated by at least two days. The procedure of the SJ was as follows: 1) the Push band was attached to the right side of a 20kg Olympic barbell, 2) the barbell was placed on the upper trapezius of the participant, 3) on the command “Go” participants lowered to a self-selected depth under control and immediately jumped as high as they could, landing in a safe manner. Participants completed two sets of three repetitions (Lake et al., 2018; O'Donnell et al., 2018), with three minutes rest between sets (Freitas de Salles et al., 2009).

Table 2: Warm up exercises performed before all four squat jump trials

Exercise	Sets x Reps
Clams or banded crab walk	1 x 20
Overhead Squats (Stick or Olympic bar)	1 x 10 e/s
BW Lunge	1 x 10
Sumo Squats	1 x 10
BW Drop squat	1 x 10
BW Squat Jumps	1 x 3

Data collection

Data for all jumps were collected using the PUSH band 2.0 (Push Inc., Toronto, ON, Canada). Data (PV) obtained from the PUSH band was recorded at a sample rate of 200Hz and sent via blue tooth to an Apple iPad running the proprietary PUSH band application (version 4.4.1). Furthermore, the highest PV value measured across the six repetitions (PV_{max}) and the average of the six repetitions (PV_{mean}) was used for analysis.

Statistical analysis

Analysis was performed using the Statistical Package for Social Science software (version 25; SPSS Inc., Chicago, IL., USA). A one-way ANOVA analysis was used to determine differences between trials. The intraclass correlation coefficient (ICC) with confidence intervals (CI) and coefficient of variation percentage (CV) was used to assess the reliability between trials and typical error (Atkinson & Nevill, 1998). The ICC was calculated using an excel spreadsheet (Hopkins, 2015), while the CV was calculated manually by dividing the SD by the mean and multiplying by 100 (Atkinson & Nevill, 1998). The strength of the ICC (<0.1 = *trivial*, 0.1-0.29 = *small*, 0.3-0.49 = *moderate*, 0.5-0.69 = *high*, 0.7-0.89 = *very high*, >0.9 = *perfect*) and CV magnitude (>10% = *poor*, 5-10% = *moderate*, <5% = *good*) was assessed using a criteria presented in previous literature (Lake et al., 2018). Statistical significant was set at $p < 0.05$. The level for all CI was set at 90%.

Results

No significant differences were found between trials ($p > 0.05$) (Table 5). Test-re-test ICC values show a *very high* to *perfect* reliability from trials one through four for both PV_{mean} (0.83-0.96, 90% CI: 0.6-0.98, mean = 0.90, 90% CI: 0.79-0.96) and PV_{max} (0.83-0.95, 90% CI: 0.59-0.98, mean = 0.91, 90% CI: 0.82-0.96) (Table 5). Furthermore, CV for PV_{mean} and PV_{max} was shown to be *moderate* across the four trials (8.7% - 9.3% and 7.9% - 9.6%) with a mean CV of 8.9% and 8.7% reported for PV_{mean} and PV_{max}, respectively (Table 4)

Table 3. Weekly training schedule (11 days) for the rowing athletes including trials one through four.

	Mon	**Tue**	**Wed**	**Thur**	**Fri**	**Sat**	**Sun**	**Mon**	**Tue**	**Wed**	**Thur**
AM	Row	Row	Row	Row	Row	Row	Row	Row	Row	Row	Row
PM	Weights/Trial 1	Row	Row	Weights/ Trial 2	Row	Rest	Rest	Weights/ Trial 3	Row	Row	Weights/ Trial 4

Table 4. PV_{max} and PV_{mean} data (Mean ± SD) for trials one to four with the coefficient of variations (CV) of each session.

			PV_{mean}					**PV_{max}**		
Trial	**1**	**2**	**3**	**4**	**Average**	**1**	**2**	**3**	**4**	**Average**
Mean ± SD ($m.s^{-1}$)	2.5 ± 0.22	2.5 ± 0.23	2.48 ± 0.22	2.49 ± 0.22	2.50 ± 0.22	2.64 ± 0.25	2.61 ± 0.23	2.61 ± 0.21	2.59 ± 0.22	2.61 ± 0.23
CV (%)	8.7	9.3	8.7	8.7	8.9	9.6	9.0	7.9	8.5	8.7

Table 5. Test-re-test reliability using intraclass correlation coefficient (ICC) with 90% confidence intervals (CI) to compare sessions and p-values to compare differences between trials one to four.

	PV_{mean}				**PV_{max}**			
Trial	**1-2**	**2-3**	**3-4**	**Mean ICC (Mean CI)**	**1-2**	**2-3**	**3-4**	**Mean ICC (Mean CI)**
ICC (CI)	0.96 (0.89-0.98)	0.83 (0.6 – 0.93)	0.90 (0.75 – 0.96)	0.90 (0.79 – 0.96)	0.94 (0.85 – 0.98)	0.83 (0.59 – 0.93)	0.95 (0.86 – 0.98)	0.91 (0.82 – 0.96)
P-value	0.86	0.89	0.94		0.79	0.97	0.85	

Discussion

The purpose of the current research was to assess the reliability of the PUSH band accelerometer, using bar mode, in measuring PV during the SJ. Based on the current literature, it was hypothesised that the PUSH band would show high reliability between sessions. The results of the current study show *very high* to *perfect* reliability (Table 5) across four trials with *moderate* CV percentages (Table 4).

Based on the findings of the current research, the bar mode application of the PUSH band 2.0 (where the band attaches to the bar) is consistent with the reliability of previous versions of PUSH band accelerometer (where the band is attached to the subject's forearms). Currently, only three studies have investigated the reliability of the PUSH band accelerometer. For example, Ripley and McMahon (2016) found high levels of reliability in the PV when performing the CMJ exercise with an Olympic barbell (ICC = 0.92). This agrees with Balsalobre-Fernandez and colleagues (2016) who observed high levels of reliability in mean (MV) and PV in the smith-machine back squat (ICC = 0.98 vs. 0.98). Both above mentioned studies attached the PUSH bands to their subject’s forearms.

Orange and colleagues (2018) found dissimilar results within his research. The result of their study only found good reliability in mean and peak power (ICC, MP = 0.8, PP = 0.83) at 20% of 1RM for the barbell back squat and MP and PP for the bench press at 40% of 1RM (ICC = 0.83 – 0.88). It was reported within their research that PV only showed moderate reliability (ICC = 0.5 to 0.74) at 20% of 1RM. Furthermore, it is interesting to note that PV tended to decrease in reliability as the intensity of the BS and BP increased (intensity range of 20 – 90% of 1RM). These results conflict with previous and the current research findings. This could be due to methodological disparities associated within each study. For example, unlike the barbell back squat exercises used in Orange and colleagues (2018) research, the smith-machine BS used in Balsalobre-Fernandez et al., (2018) study is said to restrict barbell displacement to a fixed linear path, which eliminates measurement error resulting in extraneous horizontal motion (Orange et al., 2018).

With regards to absolute reliability, the CV was used to show the degree of variability between individuals (expressed as a percentage) (Bruton, Conway and

Holgate, 2000). Scholars have suggested that an arbitrary value of < 10% to be an acceptable percentage for CV with < 5% being excellent (Atkinson & Nevill, 1998; Lake et al., 2018). The present research showed mean CV range of 8.9% for PV_{mean} and 8.7% for PV_{max} (Table 4). These results are similar to previous research on the PUSH band. Balsalobre-Fernandez et al., (2016) saw a CV of 6% while Ripley and McMahon (2016) found a CV of 2.7% for PV, respectively. Therefore the CV results in the present study show the variability with in the SJ is at an acceptable range, further solidifying the reliability of the PUSH band 2.0 bar mode application.

Conclusions

In conclusion, the bar mode application of the PUSH band has shown *very high* to *perfect* reliability when measuring PV_{max} and PV_{mean} in the SJ exercise across multiple sessions. However, practitioners must be mindful when using the device at high intensities (%1RM) as it has been recently shown that the device tends to become less reliable as intensity increases (Orange et al., 2018). Future research should focus on measuring the reliability of the bar mode application of the PUSH band on free-weight exercises (BS, BP) at moderate to high intensities (> 50% 1RM).

Practical applications

The SJ exercise is a movement that is widely used to measure an athletes lower body power output (Cormie, McCaulley & McBride, 2007b). Based on the current research, the bar mode application of the PUSH band 2.0 can enable a strength and conditioning practitioner to measure PV in the SJ (barbell only) reliably.

Chapter Three:

Study Two: The influence of velocity-based resistance training on strength and power development

Abstract

Objective: The present study aimed to investigate the use of velocity-based training zones on strength and power development compared to percentage-based training methods (%1RM). **Methods:** A total of ten physically active individuals volunteered to participate in 15 resistance training sessions over a five-week training intervention. Participants were randomly assigned (match-pair design) to either the velocity based training group (VBT, n = 5) or the traditional training group (TT, n = 5). 3RM Bench Press (BP) and Back Squat (BS) were assessed for strength, and the Squat Jump (SJ, utilising 30% of estimated 1RM BS) was used to determine power (peak velocity). **Results:** No significant differences were found between-groups for strength and power measures ($p > 0.05$). Between-group effect sizes were deemed *trivial* for BS and BP ($d = 0.00$ and 0.03, respectively), while the effect sizes for PV_{max} ($d = 0.23 \pm 0.73$) and PV_{mean} ($d = -0.38 \pm 0.59$) were deemed *unclear*. **Conclusion:** Based on the present study, VBT zones provided no significant difference in strength and power development when compared to percentage based training (%1RM). Future research should utilise a larger sample size and a more homogenous strength/training group in order to determine any potential effects.

Key Words: Movement velocity, Feedback, Strength, Power

Introduction

Strength and conditioning coaches are continually looking for the most effective and efficient ways to assess and develop strength and power characteristics for their athletes. Resistance training is considered one of the most effective ways to achieve this goal (Fry, 2004). The neuromuscular system adapts explicitly to the stimuli it is exposed to and may result in increases in muscle strength and functional performance (Pareja-Blanco et al., 2014). The manipulation of specific variables (e.g. sets, repetitions, load, movement velocity, frequency, type, rest, the percentage of 1RM, and the order of exercise selection) is vital when attempting to improve strength and power (Fry, 2004; Tan, 1999). More specifically, the manipulation of intensity (%1RM) is said to be essential to enhance strength and power.

Traditionally, the intensity is associated with the percentage of either 1RM or estimated 1RM that is lifted (Fisher et al., 2011; Peterson, Rhea, & Alvar, 2005). However, there are limitations to these methods. Performing maximal strength (1RM) tests can be impractical for large groups, time-consuming and can cause injury (Gonzalez-Badillo, Marques & Sanchez-Medina, 2011), while sub-maximal strength testing (3-10RM) significantly increases fatigue and metabolic strain resulting in decreases in force production, velocity and thereafter, the quality of subsequent sets (Gonzalez-Badillo & Sanchez-Medina, 2010). Furthermore, the acquired 1RM value attained from maximal or submaximal testing does not account for day to day fluctuations in physiology, physical performance and life stressors (Mann, Ivey, & Sayers, 2015). The ramifications of this variability may result in the intensity (%1RM) of the resistance training session either being too heavy or too light due to day-to-day fluctuations (Gonzalez-Badillo et al., 2017).

More recently, the use of ratings of perceived exertion have been used as an alternative means of prescribing intensity within resistance training sessions (sRPE). This allows for modification of sessional load based on the athlete's perceptual readiness to train or how heavy the load lifted feels (Banyard et al., 2018). Although reliable and valid (Helm et al. 2016; McGuigan & Foster, 2004), the sRPE method can be problematic due to the subjective nature and the requirement of the prescribed number of repetitions in a set to be completed before adjustment of load can be made (Banyard et al., 2018). For these reasons, a training method that comprises of immediate external feedback to prescribe intensity in an objective manner is needed to enhance training adaptations and to avoid muscular failure.

Advancements in technology have enabled specific variables, such as movement velocity, to be relayed back instantaneously after every repetition within resistance training sessions. Termed velocity-based training (VBT), the notion of using movement velocity to achieve specific performance goals has been gaining popularity in strength and conditioning facilities and also within the research literature (Gonzalez-Badillo et al., 2011; Gonzalez-Badillo & Sanchez-Medina, 2010; Mann et al., 2015; Pareja-Blanco, Rodriguez-Rosell, Sanchez-Medina, Gorostiaga & Gonzalez-Badillo, 2014). Research has shown that monitoring repetition velocity is an objective indicator of the acute metabolic stress and mechanical fatigue induced by resistance training (Moran-Novaro et al., 2018). Indeed, there is an inverse relationship between fatigue and movement velocity, that is, when fatigue increases, movement velocity decreases (assuming effort is maintained) (Gonzalez-Badillo et al., 2011; Izquierdo et al., 2009).

The use of velocity cut-offs (VC) has been proposed to monitor fatigue within training sets, while also improving strength and power. This approach involves the cessation of a set once the velocity has dropped by a pre-determined percentage (Perez-Castilla, Garcia-Ramos, Padial, Morales-Artacho, & Feriche, 2018). Contention exists over what is the optimal VC for strength and power. Numerous researchers and practitioners have seen improvement in strength utilising a 20-40% VC, while power variables improve using VC < 10% (Pareja-Blanco et al., 2017a; Pareja-Blanco, Sanchez-Medina, Suarez-Arrones, & Gonzalez-Badillo, 2017b; Perez-Castilla et al., 2018).

Thus, the purpose of the present study is to determine if specific velocity zones, utilising a VC, is more effective in enhancing strength and power development compared to percentage-based training methods (%1RM).

Methodology

Subjects

Ten physically active participants volunteered to take part in the current study. Participants were randomly assigned to either a traditional training group or a velocity-based training group. Physical characteristics of the participants are detailed in Table 1. Inclusion criteria comprised of: 1) no current acute or chronic injuries; 2) aged between 18-36 years; 3) two years of resistance training experience; 4) were proficient at performing the bench press, back squat and squat jump; 5) not taking any performance enhancing or banned substances. Before the beginning of the pre-testing, the subjects were informed of the risks and provided written informed consent. Participation was voluntary, and participants had the option to withdraw at any time. The University of Waikato Human Ethics Committee provided ethical approval.

Table 1. Physical characteristics of VBT and TT group

	VBT (n = 5)	**TT (n = 5)**
Age (years)	27 ± 7	31 ± 4
Training Age (years)	7 ± 4	5 ± 1
Body Mass (Kg)	85 ± 16	86 ± 17
Height (cm)	179 ± 10	178 ± 10

Testing

Pre and post testing occurred one week before and after the intervention. Each testing session started with a specific ten-minute warm-up which involved a five-minute cycle or row at approximately 50% of maximal effort, followed by dynamic stretches and mobility exercises (Table 2). Following the warm-up, strength tests were completed which consisted of a 3RM back squat (BS) and a 3RM bench press (BP) for lower and upper body strength, respectively. The squat jump (SJ) was performed last to accurately utilise 30% of the estimated 1RM BS weight.

The protocol for establishing the 3RM BS and BP was adapted from Helm et al., (2016). The participants commenced with warm-up sets, working at an estimated 60% of 1RM for five repetitions, 70% 1RM for three repetitions, 80% 1RM for three repetitions, and from then on the participants continued to increase the weight until they lifted the highest load possible for three repetitions. Three minutes rest was allowed between all sets (Freitas de Salles, et al., 2009). When the maximum weight was lifted for three repetitions, the test ceased, and this load was used to predict a 1RM value using the following equation by Brzycki's (1993):

Predicted 1RM = Weight Lifted/1.0278 – 0.0278X

(X = No. of reps performed)

This equation has been proven to be a reliable method of predicting estimated 1RM value ($r^2 = 0.98$) (Brzycki's, 1993).

For the SJ, all participants utilised the PUSH band accelerometer to determine peak velocity (PV) for the jumps. Participants loaded a 20kg Olympic barbell with 30% of their estimated 1RM BS weight. They then lowered down to a self-selected depth and immediately jumped as high as they could, landing safely. The participants performed two sets of five repetitions with three minutes rest between sets. The highest PV achieved and the average PV across the two sets was used for data analysis.

Table 2. Pre and post testing mobility exercises for VBT and TT groups

Exercise	Sets x Reps
- Overhead Squats (Stick or Olympic bar)	1 x 10
- Cable face pulls	2 x 10
- KB Squats	1 x 15
- KB Single leg RDLs	1 x 10
- Front plank - Right side plank - Left side plank	30s 15s 15s X2
- Alt arm/leg raise	1 x 10
- Drop Squats	1 x 12

Research design

Once pre-testing was completed, participants were randomly assigned to either the VBT group or the TT group for the five-week training intervention utilising a matched-pairs design. They were paired by strength level (e.g. one and two, three and four), and then randomly assigned to either group (Portney & Watkins, 1993). The descriptive characteristics of the TT and VBT programs are shown in Table 3. The training volume (sets, repetitions, intensity, and rest) for both groups were identical. The BS, BP, and SJ were included into both the VBT and TT groups training programs. The five-week period was split into a light intensity (weeks three and six), moderate intensity (one and four), and hard intensity weeks (two and five). The sets and repetitions ranged from three to four sets with three to six repetitions, with three minutes rest between sets.

The TT groups training load was based on their estimated 1RM for the BS and BP. The TT group utilised a percentage range of 65% to 87.5% of the athletes estimated 1RM. These percentages are recommended for increasing maximal strength (Fisher et al., 2011; Tan, 1999). The participants were not given a specific velocity zone to maintain. They were instructed to move the weight at a self-selected speed. They only adjusted the weight lifted if instructed to by the allocated program (i.e. week 1-75%, week 2 – 80% etc.).

In contrast, the VBT group utilised the PUSH band accelerometer (2.0) to monitor their velocity and provide external feedback. The PUSH band has proven to be a reliable and valid (when the band is placed on the forearm of the subject) means of measuring velocity, specifically, peak velocity (PV) and mean velocity (MV) (Balsalobre-Fernandez, Kuzdub, Poveda-Ortiz, & Campo-Vecino, 2016). The VBT group were given specific velocity zone's (PV or MV) to maintain for each exercise. For example, the SJ exercises utilised PV zones between 2.2-2.4m.s^{-1}, while the BS and BP used MV zones of 0.5 – 0.6m.s^{-1}. These zones were adapted from research conducted by Baker, (2018), Mann, (2013) and Mann et al., (2015), in which they correspond to the enhancement of maximal strength (BS, BP) and power (JS). The focus for the VBT group was maintaining the velocity zone and not the weight lifted. If the participant was not meeting the velocity zones for the set, they then adjusted accordingly (either increase or decrease weight) until they were within the zone. The VBT group were informed to perform maximal effort during each set and were provided external feedback after every repetition to further aid in motivation to perform maximal effort for every repetition.

Velocity cut-offs (VC) were utilised within the VBT group. VC is a variable in which the set is stopped because of a decrease in the percentage of velocity over a set. For this study, a 10% VC off was set for the power based exercises (SJ) and a 20% VC off for the strength exercises (BP & BS) (Pareja-Blanco et al., 2017b; Sanchez-Medina and Gonzalez-Badillo, 2011).

Table 3. Descriptive characteristic for TT and VBT groups

Traditional Training Program (TT)					
	Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Training week intensity	**Moderate**	**Heavy**	**Light**	**Moderate**	**Heavy**
BB Squat Jump					
Sets x Reps	3 x 5	3 x 5	3 x 5	3 x 5	3 x 5
%1RM	30%	40%	30%	40%	50%
BB Bench Press					
Sets x Reps	3 x 6	4 x 5	3 x 6	4 x 3	5 x 3
%1RM	75%	80%	70%	85%	87.5%
BB Back Squat					
Sets x Reps	3 x 6	4 x 5	3 x 6	4 x 3	5 x 3
%1RM	75%	80%	70%	85%	87.5%
Velocity-Based Training program (VBT)					
BB Squat Jump					
Sets x Reps	3 x 5	3 x 5	3 x 5	3 x 5	3 x 5
VBT Zone	2.2 – 2.4 m.s^{-1}				
BB Bench Press					
Sets x Reps	3 x 6	4 x 5	3 x 6	4 x 3	5 x 3
VBT Zone	0.5 - 0.6 m.s^{-1}				
BB Back Squat					
Sets x Reps	3 x 6	4 x 5	3 x 6	4 x 3	5 x 3
VBT Zone	0.5 - 0.6 m.s^{-1}				

Forms of Analysis

Analysis was performed using Statistical Package for Social Science software (version 25; SPSS Inc., Chicago, IL., USA). Percentage of weight increase was recorded post-test to determine improvements. PV was recorded for the SJ during post-testing. Means and standard deviations (SD) were calculated to explain all variables. A one-way ANOVA analysis was performed to compare the effects of both groups (TT vs VBT) over time for all measures. Effect sizes were calculated using Cohen's *d* and interpreted using thresholds of 0.2, 0.6, 1.2 and 2.0 for *small, moderate*, *large* and *very large* (Portney & Watkins, 1993). A significance level of $p < 0.05$ was used to indicate statistical significance.

Results

All data are expressed as means ± SD. No significant difference existed between groups for any physical characteristics at baseline ($p > 0.05$) (Table 1). Analysis between pre and post measures showed no significant improvements in both the TT and VBT training groups for BS, BP, PV_{max} and PV_{mean} ($p > 0.05$). Furthermore, no significant improvements were found between groups for all measures ($p > 0.05$) (Table 4). Between group effects size were deemed *trivial* for BS and BP ($d = 0.00 \pm 0.10$ and 0.03 ± 0.20 respectively), while the positive and negative effects found for PV_{max} ($d = 0.23 \pm 0.73$) and PV_{mean} ($d = -0.38 \pm 0.59$) were deemed *unclear* (Table 4). Finally, a 2.1% difference in total repetitions completed post intervention was found between TT (642 repetitions) and VBT (629 ± 5 repetitions) groups (Table 5).

Table 4. Pre and post intervention strength and power results (Mean ± SD) for traditional and velocity-based training groups with p-values and effect sizes for the comparison of change between groups.

	Traditional Training (TT)				***Velocity-Based Training (VBT)***				***One-way ANOVA (p-value)***	***Effects size (ES) ±90% Confidence Interval***	
	Pre	***Post***	***% Diff***	***p-value***	***Pre***	***Post***	***%Diff***	***p-value***			
Est. 1RM BP (Kg)	81 ± 37	88 ± 38	+ 9.2	0.76	84 ± 25	92 ± 29	+10.2	0.63	0.87	0.03 ±0.20	*Trivial*
Est. 1RM BS (Kg)	109 ± 40	124 ± 43	+ 13.6	0.59	126 ± 38	141 ± 36	+11.8	0.54	0.52	0.00 ±0.10	*Trivial*
PV$_{max}$ (m.s^{-1})	2.46 ± 0.19	2.43 ± 0.22	- 1.3	0.81	2.45 ± 0.20	2.46 ± 0.14	+0.5	0.91	0.80	0.23 ±0.73	*Unclear*
PV$_{mean}$ (m.s^{-1})	2.19 ± 0.16	2.32 ± 0.19	+ 6.2	0.26	2.26 ± 0.21	2.32 ± 0.15	+2.9	0.58	0.99	-0.38 ±0.59	*Unclear*

Table 5. Repetitions completed for TT (Mean) and VBT (Mean ± SD) after the five-week intervention.

	TT	VBT	% Diff
Bench Press	216	211 ± 4	2.1%
Back Squat	216	213 ± 1	1.4%
Squat Jump	210	204 ± 3	2.7%
Total	642	629 ± 5	2.1%

Table 6. Mean ± SD of intensity (%1RM) between the VBT and TT groups for the BP, BS & SJ across the five-week training intervention.

		Week 1	Week 2	Week 3	Week 4	Week 5
Bench Press	VBT	80 ± 4%	83 ± 8%	83 ± 9%	84 ± 6%	84 ± 7%
	TT	75%	80%	70%	85%	87.5%
Back Squat	VBT	78 ± 1%	80 ± 2%	81 ± 3%	86 ± 3%	89 ± 3%
	TT	75%	80%	70%	85%	87.5%
Squat Jump	VBT	32 ± 3%	34 ± 4%	34 ± 4%	35 ± 5%	37 ± 5%
	TT	40%	50%	30%	40%	50%

Discussion

The current study investigated the influence of VBT zones (MV or PV) on strength and power development compared to traditional percentage-based training methods (TT; %1RM). The main findings of the present study showed no significant difference between pre and post measures of strength and power for both TT and VBT groups ($p < 0.05$). Furthermore, there was a lack of statistical significance observed between-groups for all measures.

Despite the lack of significance, increases in strength were observed at the conclusion of the training for the BS (VBT = 12%, TT = 13%) and BP (VBT = 10%, TT = 9%), respectively. This indicates that both groups responded positively to the training and improved in strength despite the lack of statistical significance presented and methods used. The VBT percentage increases in the present study agree with previous investigations on VBT. Pareja-Blanco et al., (2017a) reported BS improvements of 13.4%, while Torres-Torrelo and colleagues (2017) found a 17% increase in their research. Similarly, Gonzalez-Badillo, Rodrigues-Rosell, Sanchez-Medina, Gorostiaga, and Pareja-Blanco, (2014) reported significant increases in BP 1RM following six weeks of maximal velocity resistance training (18.2%). Furthermore, increases in strength following TT are in agreement with previous research. Cormie, McGuigan and Newton (2010) reported BS improvements of 31% using untrained participants after ten weeks of periodised resistance training. Ahtiainen and colleagues (2003) reported 20.9% increase in maximal force, while Campos et al., (2002) saw statistically significant results in pre to post BS strength ($p < 0.05$) after 21 weeks of resistance training. It is important to note that the studies mentioned had significantly longer durations when compared to the present research, which could have contributed to the larger improvements achieved within their respective studies.

One reason behind the percentage changes reported could be due to the training status of the participants. The training status of the participants can knowingly influence the adaptations following a specific intervention. Lesser trained subjects have been known to produce superior adaptations compared to trained individuals (Baker, 2001a; Behm, 1995; Cormie et al., 2010; Rhea, Alvar, Burkett, & Ball, 2003). This could be due to accelerated neural alterations such as greater recruitment of motor units, increased rate coding and greater reflex potential (Behm, 1995). In addition, another reason could be due to the intensity (%1RM) in which both groups trained at throughout the five-week intervention. Researchers have reported that short-term (< 5 weeks) enhancements of maximal strength are due to neuromuscular contributions and occur at intensities > 80% of 1RM (Baker, Wilson, & Carlyon, 1994; Folland & Williams, 2007). Furthermore, Rhea and colleagues (2003) state that lesser trained subjects can see neuromuscular improvements at intensities above 60% of 1RM. The specific VBT zone to enhance strength was 0.5-0.6m.s^{-1}, which was adapted from Mann et al. (2015). The current research has found the strength based velocity zones correspond to an intensity (%1RM) range of 80-84% for the BP and 78-89% for the BS, across the five-week intervention (Table 6). Additionally, the TT training group utilised intensity ranges of 75-87.5% of 1RM for strength training. Thus, the percentage increases in strength mentioned in the present study could be due to neuromuscular adaptations as a result of the high intensities utilised (> 80%) across the five-week intervention.

The present study saw a small percentage increases of 0.5% and 2.9% in the VBT group for PV_{max} and PV_{mean}, respectively, while the TT group saw a 6.2% increase in PV_{mean} only. Pareja-Blanco et al., (2014) reported an 8.9% increase in the CMJ after six weeks of VBT, while McBride and colleagues (2002) saw significant ($p < 0.05$) increases in PV and peak power (PP) in SJ exercise over eight weeks. It is suggested that neuromuscular power is achieved at intensities < 60% of 1RM (Bevan et al., 2010; Kawamori & Haff, 2004; Thomas et al., 2007). The TT group utilised intensities that range from 30-50% of 1RM. The present research found the average intensity for the velocity zone (2.2-2.4m.s^{-1}) used in the VBT group was 32-37% across the five-week intervention. Previous research indicates that optimal power output (PO) occurs at approximately 30% of an athletes 1RM (Bevan et al., 2010; Kawamori & Haff, 2004; McBride et al., 2002; Thomas et al., 2007). This could provide a rationale for the increase in SJ PV in the current study for both training groups. However, it should be noted that there is still contention within the literature as to what is the optimal intensity for the increase in PO as research has also shown that higher intensities (> 60% 1RM) can elicit improvement in PO

(Cormie, McGuigan, & Newton, 2011; Kawamori & Haff, 2004; McBride et al., 2002).

The present data suggest that using movement velocity to determine load and repetitions can result in a reduction in training volume (sets x reps) while still showing favourable increases (%) in strength and power. This is confirmed by Pareja-Blanco and colleagues (2017a) who investigated VC of two different groups; one using a VC of 20% (VC20) and the other using 40% VC (VC40). A significant difference in repetitions completed was found between the groups ($p < 0.05$), with the VC20 group performing 40% fewer repetitions than the VC40 group. Furthermore, performance results indicated that despite the difference in repetitions completed between groups, VC20 saw similar strength improvements in the BS and superior enhancement in CMJ ability when compared to VC40 group. In comparison, the VBT group of the present study saw a decrease of 2.1% for the BP, 1.4% for the BS, 2.7% for SJ and a total difference of 2.1%. It should be noted that the TT group performed all repetitions stated in the resistance training program. Furthermore, the research by Pareja-Blanco et al., (2017a) did not explicitly state training volume (sets x reps) that was used in their research, only that both interventions used the same relative loading magnitude (%1RM) and different VC. In contrast, training programs for the present study were similar in volume (sets x reps) for both training groups (TT & VBT) with the only differing factor being the TT group using a %1RM and the VBT group utilising real-time movement velocity to determine load.

Several limitations existed that may have influenced the current study results. Firstly, the subjects utilised within the study did not have a high level of resistance training background. Although the subjects had performed the movements in the study before the beginning of the intervention with adequate technique, the level of strength between them was vastly different as evident by the large standard deviations of the strength-based exercises (BP, BS). Secondly, due to the low sample size (coupled with the varying strength levels), this may have been a cause for the lack of statistical significance within the current research. Higher sample size could have resulted in a better understanding of the present results and provided statistical power by detecting a treatment effect (Beck, 2013). Thirdly, during the pre and post measure of SJ, the PUSH band that was used to measure PV was at times inconsistent, meaning repetitions were at times not being picked up by the device.

Conclusion

The results of this research show there to be no significant difference between TT and VBT in all variables measured. While small improvements were evident in both training groups, the small increases were not different between training methods. Future research is warranted and should consist of larger sample sizes and more homogenous groups to allow a more comprehensive comparison of training methods.

Practical applications in sport

VBT has been shown to provide enhancements of strength and power variables during resistance training (Pareja-Blanco, et al., 2017a). Although the results in the present study did not show a difference between using VBT and TT both groups did improve strength over the five-week training intervention. Based on existing literature it would appear that strength and conditioning practitioners may consider whether VBT could add value to their existing programming methods.

Chapter Four:

Future Research

Future Research

The following recommendations are made for future research:

Study One:

- Debate exist over the current validity of previous versions of the PUSH band devices (when attached to the forearm and waist belt). Therefore, future research should establishing the validity of the PUSH band, bar mode application, against gold standard devices.
- Whilst the reliability of the PUSH band was deemed satisfactory in the SJ exercise, future research should confirm the reliability of the PUSH band bar mode application on additional free-weight traditional exercises (e.g. back squat, bench press, and deadlifts).
- In addition, recent research has shown that the PUSH band device becomes less reliable as intensity (%1RM) increases (when device is attached to the forearm). Therefore, future research should further explore the reliability of the PUSH band bar mode application on a range of intensities (e.g. 20-90% of 1RM) on traditional free-weight exercises.

Study Two:

- The present research was lacking in statistical power due to the small sample size and variation in strength ability and changes. Future research should employ a larger sample size and more homogenous subjects/athletes to allow a more comprehensive comparison of training methods.
- Currently, contention exist over what the optimal velocity training zone is for a specific resistance training goal. More research is needed in order to clarify the specific velocity zones for the development of strength and power.
- More research is needed to establish optimal VC zones for the development of strength and power.
- Lastly, future research should look to employ a longer intervention (> 5 weeks) with additional strength and power free-weight exercises (e.g. Deadlifts, Power Cleans, Snatch)

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Appendices

Appendix 1 – Research Consent Form

Consent Form for Participants

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

The Influence of Velocity-Based Training on Neuromuscular Strength and Power Development

Consent Form for Participants

I have read the **Participant Information Sheet** for this study and have had the details of the study explained to me. My questions about the study have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I also understand that.

Tick the box

- ☐ I am free to withdraw myself and any information I have provided for the study within three weeks after the final session date.

I agree to provide information to the researchers under the conditions of confidentiality set out on the **Participant Information Sheet**.

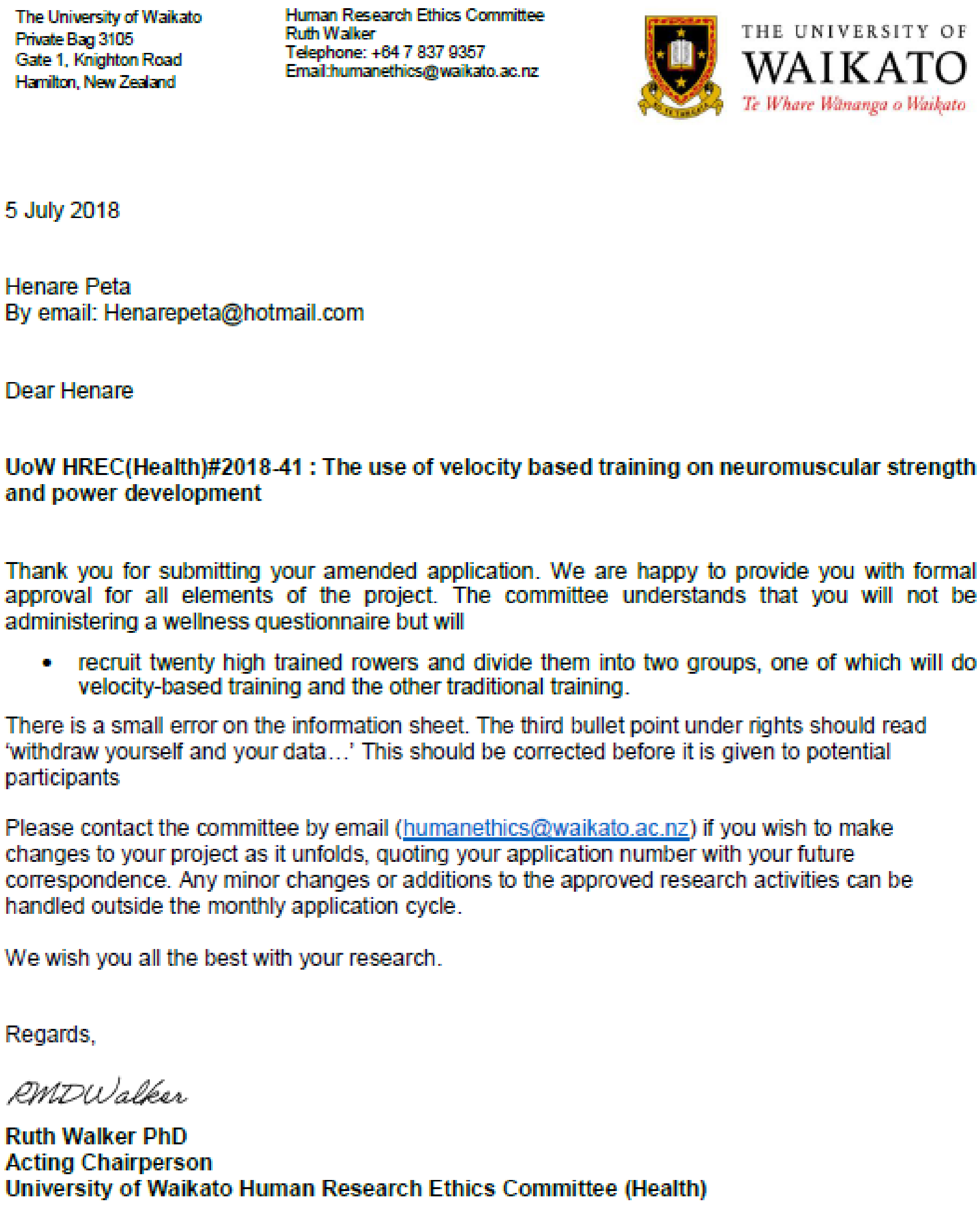
I agree to participate in this study under the conditions set out in the **Participant Information Sheet**.

Signed: ______________________________

Name: ______________________________

Date: ______________________________

Appendix 2 – Ethical Approval



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Human Research Ethics Committee
Ruth Walker
Telephone: +64 7 837 9357
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THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

5 July 2018

Henare Peta
By email: Henarepeta@hotmail.com

Dear Henare

UoW HREC(Health)#2018-41 : The use of velocity based training on neuromuscular strength and power development

Thank you for submitting your amended application. We are happy to provide you with formal approval for all elements of the project. The committee understands that you will not be administering a wellness questionnaire but will

- recruit twenty high trained rowers and divide them into two groups, one of which will do velocity-based training and the other traditional training.

There is a small error on the information sheet. The third bullet point under rights should read 'withdraw yourself and your data…' This should be corrected before it is given to potential participants

Please contact the committee by email (humanethics@waikato.ac.nz) if you wish to make changes to your project as it unfolds, quoting your application number with your future correspondence. Any minor changes or additions to the approved research activities can be handled outside the monthly application cycle.

We wish you all the best with your research.

Regards,

RMDWalker

Ruth Walker PhD
Acting Chairperson
University of Waikato Human Research Ethics Committee (Health)