POST-ACTIVATION POTENTIATION OF TRUNK ROTATIONAL MOVEMENT ON PUNCH POWER OUTPUT IN AMATEUR BOXERS

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Master of Research

Abstract

This study aimed to investigate the post-activation potentiation (PAP) effect of a woodchop conditioning activity combined with an elastic resistance band on enhancing punching impact power among fifty-three amateur boxers (age = 21.8 ± 4.7 years). The experimental protocol began with a pretest measuring punch impact power for rear hook, cross-punch, and frontal hook. Subsequently, participants underwent a PAP warm-up, which included a woodchop conditioning activity with an elastic resistance band at a moderate intensity, followed by a 7-minute rest interval. A one-group pretest-posttest design was utilised to assess changes in impact power before and after the intervention. The data revealed that participants exhibited significantly greater punching impact power after completing the PAP protocol ($p < .05$). However, effect size (d) was trivial ($d < 0.20$). The data was then stratified into subgroups based on competitive level (Open-class vs. Development) and Resistance Training (RT) experience (Advanced vs. Novice). Results indicated that although significance difference was found in all three punch variations in the Development group, the effect size remained trivial. In contrast, although the Open-class group only showed significance in both the rear hook and frontal hook, the magnitude of the difference between groups was small in all three punch variations ($d = 0.2$-0.6). Analysing the data based on RT experience, the Novice group reported a significant difference in all punches with trivial effect sizes. Meanwhile, the Advanced group exhibited significance in the rear hook and frontal hook, but no significance in the cross-punch. Nevertheless, all three punches showed small effect sizes. In summary, the findings suggest that when combined with a woodchop conditioning activity and an elastic resistance band, PAP may lead to improvements in punch performance. Coaches and athletes seeking novel approaches to enhance performance may find this information valuable. However, it's important to note that while participants did punch with greater impact post-PAP, those with greater resistance training experience and of higher competitive level should a greater PAP sensitivity. Further research may be needed to explore the practical significance of these findings.

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PAP	Post-activation Potentiation
CMJ	Countermovement Jump
PAR-Q	Physical Activity Readiness Questionnaire
RT	Resistance Training

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Dedication

I would like to dedicate this to my parents, who without I wouldn't be able to be where I am today. I also extend my dedication to my cherished wife, who has been a constant pillar of strength and encouragement during the challenging years of this endeavor. Furthermore, I dedicate this work to my precious daughter, Khadija, whose arrival just one month before my final submission served as a profound source of inspiration and motivation, propelling me across the finish line.

Chapter 1: Introduction

The capacity to generate force rapidly, a fundamental aspect of power, holds significant relevance across a multitude of sports. Athletic performance is inherently 'force and time-dependent,' a concept highlighted by Turner (2009). Athletes, therefore, face the imperative task of exerting maximal force in the shortest possible time to optimise their performance. It has been established that there is a link between power and performance variables in sports (Kraemer et al., 2001), with recent research advocating for the development of power as a means of improving athletic performance in ballistic sporting activities such as jumping, kicking, sprinting and punching (Hedrick, 2007; Campo et al., 2009; Loturco et al., 2014; Bolger et al., 2015; Rumpf et al., 2016). In boxing, the ability to deliver a punch with a high kinetic impact is viewed as a determining factor in victory (Pierce et al., 2006; Smith, 2006; Lenetsky et al., 2013). Previous research has examined kinetic and kinematic variables such as head contact, punch velocity, ground reaction force, muscle recruitment sequences, and trunk rotation to gain a better understanding of the factors affecting punch performance (Walilko et al., 2005; Cabral et al., 2010; Lenetsky et al., 2013; Cheraghi et al., 2014; Kimm and Thiel, 2015; Tong-Iam et al., 2017). Although these studies emphasise the critical role of power training in optimising athletic performance, there is no consensus on the optimal training method for developing maximum power. Since a boxer's ability to win a bout may well be enhanced by improving their striking power, developing greater punching impact power should be an essential component of a boxer's training programme.

Whilst athletes may improve their strength and power via a variety of training approaches, a recent concept known as post-activation potentiation (PAP) has emerged as a strategy to enhance explosive power, with extensive research conducted on the method (Carter and Greenwood, 2014; Cavaco et al., 2014; Lim and Barley, 2016). PAP is a phenomenon in which a conditioning activity at maximum or near-maximal effort is combined with a biomechanically similar explosive action to elicit a greater level of short-term power output (Mcbride et al., 2005; Robbins, 2005). Numerous studies have advocated for the use of PAP during warm-up protocols to optimise the performance of explosive actions during the initial stage of the training or competition (McBride et al., 2005; Docherty and Hodgson, 2007; Farup and Sorensen, 2010; Wilson et al., 2013; Dolan et al., 2017;). Considering that punch performance is closely linked to the outcome of a bout in boxing, it stands to reason that enhancing punching power as part of a pre-bout warm-up routine could potentially increase the likelihood of victory. Short-termm performance improvement following PAP training has been well documented in the literature (Matthews et al., 2009; Comyns et al., 2010; Chen et al., 2017). However, some data in the literature challenge PAP's usefulness in improving performance (Duthie et al., 2002; Chiu et al., 2003; Hanson et al., 2007; Till and Cooke, 2009; DeRenne, 2010). Some of these inconsistencies have been attributed to many variables, including athletes's training history, muscle fibre composition, exercise intensity, rest interval between ballistic action and PAP, as well as exercise specificity (Hamada et al., 2003; Arabatzi et al., 2014). The effectiveness whereby a loaded exercise stimulates PAP may be compromised by the rest period (Kilduff et al., 2007), with a balance needed between PAP and induced muscular fatigue (Sale, 2004) to improve athletic performance. PAP-inducing preloading exercise bouts must consider the individual's training experience, the volume of the exercise, and the intensity at which the bout is performed. The results of a prior meta-analysis undertaken by Wilson et al. (2013) highlighted greater PAP benefits in well-conditioned athletes when compared with untrained athletes. It also found rest intervals between 7 to 10 minutes and a moderate-intensity level ranging from 60% to 84% to be most optimal in inducing a greater PAP effect. Previously, Buttifant and Hrysomallis (2015) found improvements in acute power when warm-up protocols using box squats with elastic resistance bands at moderate intensity were used to elicit PAP, with a 12-13% increase observed in both the 5 and 10-minute rest interval.

The characteristics of the individuals may also influence PAP effectiveness. With well-trained, stronger and more powerful individuals were shown to be more sensitive to the impact of PAP when compared to untrained, weaker and less powerful participants (Chiu et al., 2003; Gourgoulis et al., 2003; Kilduff et al., 2007; Wilson et al., 2013; Seitz et al., 2014. Previously Chiu et al. (2003) found improvements in countermovement jump and drop jump heights of 1–3 % in resistance-trained participants but a decline in the performance of 1–4 % in recreationally trained individuals after a heavy resistance training PAP protocol. This is consistent with earlier findings which have shown that individuals with shorter twitch muscle contraction times and a more significant proportion of type II fibres were susceptible to a greater PAP effect (Hamada et al., 2000; Chiu et al., 2003; Hamada et al., 2003; Arabatzi et al., 2014). Previous research by Requena et al. (2011) found that individuals involved in maximum-intensity exercises which rely on type II muscle fibre such as sprinting and jumping generated greater PAP responses for the working muscles. It has been proposed that PAP is increased in type II muscle fibres due to a rise in phosphorylation of myosin regulatory light chains in response to the conditioning activity (Chiu et al., 2003; Sale, 2004; Hodgson et al., 2005). This further results in an increase in actin-myosin sensitivity to Ca2+ (Sweeney et al., 1993; Hodgson et al., 2005), which in turn allows for an increase in cross-bridge force production (Vandenboom, 2004). Another possible explanation for this phenomenon is that the motor unit precontraction stimulus increases excitability, potentially resulting in neuromuscular changes such as increased recruitment and synchronisation of motor units (Kilduff et al., 2007). It is important to note that PAP has a very individualise response, with the impact of the potentiation being affected by characteristics such as volume, intensity, specificity of the conditioning activity, muscle fibre type, resistance training experience, and competitive level (Kilduff et al., 2007; Seitz et al. 2014).

The specificity of the conditioning activity must also be considered when designing PAP protocol Hodgson et al. (2005), with previous research showing greater potentiation when a biomechanically similar conditioning activity is paired with the explosive action (Yetter and Moir, 2008; Crewther et al., 2011; Esformes et al., 2013; Whelan et al., 2014). The cable woodchop is a conditioning activity that resembles movement patterns seen in throw-like motions such as golf swing, tennis serve, and boxing punches. It can be considered specific to sports that utilise throw-like sequences. According to Keogh et al. (2009), higher-skill golfers had a greater clubhead velocity (12%) and cable woodchop strength when compared to those with less skill. This suggests that incorporating the cable woodchop exercise into a PAP protocol could lead to improved performance in sports that involve a similar movement pattern. Movement patterns and proximal-to-distal sequencing of the kinetic chain are comparable between the woodchop conditioning activity, the golf swing, and the punching motion in boxing (Liebenson, 2003; Spaniol, 2012; Cheragi et al., 2014; Dinu et al., 2020; Chen et al., 2017). In each of these three movements, the power is generated in the legs and then transmitted to the arms and hands via the trunk, and shoulders (Hume et al., 2005; Cabral et al., 2010; Kovacs and Ellenbecker, 2011; Cheraghi et al., 2014). Given the similarities between the woodchop and the movements required for sports like boxing, it stands to reason that using the woodchop as a conditioning activity during PAP could induce a PAP response in such activities.

Recent research has shown that PAP can induce short-term enhancements in performance, especially in explosive movements (Matthews et al., 2009; Comyns et al., 2010; Chen et al., 2017). Several factors, including an individual's training history, muscle fibre composition, exercise intensity, rest intervals, and exercise specificity, play pivotal roles in shaping the effectiveness of PAP (Hamada et al., 2003; Arabatzi et al., 2014). Yet, numerous questions about PAP remain unanswered. Specifically, the impact of sport-specific conditioning activities, an athlete's competitive level, and their resistance training experience levels on PAP responses requires further exploration (Duthie et al., 2002; Chiu et al., 2003; Hanson et al., 2007). These variables may significantly affect the effectiveness of PAP protocols (Till and Cooke, 2009; DeRenne, 2010).

In summary, the current study aims to explore the potential of PAP to enhance punch performance in boxing. Building upon existing research, three hypotheses are proposed: 1) Differences in punch performance improvements will be observed among participants after an elastic resistance band woodchop conditioning activity. 2) Competitive levels will affect PAP responses, with higher-level competitors experiencing more significant enhancements. 3) Training experience will influence the extent of the PAP response, with more experienced individuals showing greater improvements in punch performance.

Chapter 2: Literature Review

2.1 HISTORICAL BACKGROUND

For more than a century, boxing has been a mainstay of the combat sports landscape, attracting fans worldwide. England Boxing (formerly known as the ABA) oversees the development and regulation of the sport in England (England Boxing, 2020). To provide a level playing field for all participants, amateur boxing has a weight class system in which boxers are divided into 11 different weight categories. In addition to weight category, boxers are also split into two levels of classification depending on the number of bouts they had competed in Development-class: Male (≤20 bouts), Female (≤15 bouts); and Open-class: Male (≥20 bouts), Female (≥15 bouts), predicated on the idea that boxers who have competed in a higher number of bouts are at a higher level of ability (England Boxing, 2020).

The classification of boxers into different levels based on the number of bouts they have competed in assumes that skill level inherently increases with each bout. While the categorisation system is rooted in the number of bouts, it's important to exercise caution, as this assumption might not accurately reflect skill level. Various factors, including the quality of opponents faced and the intensity of training, can significantly impact a boxer's skill development.

The concept of categorising by experience could potentially be flawed due to these complex variables. One potential solution to enhance the classification of boxers' experience levels could involve incorporating additional metrics alongside the number of bouts, such as assessing the quality of opponents faced or considering performance outcomes. This multifaceted approach would provide a more comprehensive evaluation of a boxer's skill and experience, mitigating some of the limitations associated with relying solely on the number of bouts to determine their level. However, despite its potential limitations, the number of bouts remains one of the most practical and widely used indicators of experience in the boxing community. It provides a straightforward way to differentiate between boxers at different stages of their careers. While acknowledging the potential drawbacks, the current classification system based on the number of bouts is the most appropriate method available to assess and categorise boxers' experience levels systematically.

A key component of winning in boxing is to land punches at an opponent without getting hit. Winners in boxing are decided based on points victory or a most common stoppage win. Points victory are determined after the prescribed number of rounds has been completed, and the scoring judges have determined the winner (England Boxing, 2020). A knockout (KO), on the other hand, is the second and most sought-after way in which to obtain victory. There are multiple ways in which KO occurs: 1) boxer is knocked down and fails to resume boxing before the referee counts to ten, 2) boxer is unfit to continue following a knockdown; 3) referee stops the bout due to a boxer being dominated and outclassed; or 4) referee bringing a halt to the bout due to the recommendation of the ringside doctor (England Boxing, 2020). Consequently, punch impact, which is both powerful and accurate, is a desirable attribute due to its influence on the outcome of the bout.

2.2 PUNCH MECHANICS

With a knockout being a constant aim in a bout, improving punch performance has been recommended by several authors to enhance knockout power (Cheraghi et al., 2014; Loturco et al., 2016).

Previously, Cheraghi et al. (2014) stated that a sequential kinetic chain (from proxim al to distal) must be followed in order to achieve optimal punch performance. When performing a punch and other similar biomechanical thrown-like motions such as throwing, batting, striking, and kicking, the movement is initiated by musculoskeletal forces that are transmitted to the ground, upon which a comparable force is redirected back to the larger proximal segment of the body (lower body). This procedure enables momentum to be transferred to the trunk and ultimately toward the distal end in which it can be directed to an object (Escamilla et al., 2009; Roetert et al., 2009), or in the case of boxing, the opponent (Markovic et al., 2016; Tong-Iam et al., 2017). According to the findings of various studies, efficient coordinated phasing of the kinetic chain is an important factor in determining ball velocity between different levels of golf proficiency (Myers et al., 2008). The kinetic chain is a notion in which the linked segments of the musculoskeletal are influenced by one another in order to generate a sequencing phase of events starting from the larger proximal joints and terminating at the smaller distal segments.

Figure 1 illustrates the mechanics of the cross and hook punches. Previous research have looked at the biomechanics of the cross and hook punches in boxing and have observed their sequential patterns and characteristics to dissect the mechanics of punch performance (Filmonov et al., 1985; Smith et al., 2016; Dinu and Louis, 2020; Dinu et al, 2020; Stanley, 2020). The cross-punch, characterised by its linear trajectory, involves intricate coordination between the lower body, trunk rotation, and arm extension. While trunk rotation is significant in both punches, the cross-punch relies on a more controlled and intense linear rotation. The goal is to generate maximal force directed towards the opponent in a straight line. This linear rotation is a hallmark of the cross-punch's effectiveness, allowing for powerful, straight shots (Dinu and Louis, 2020; Dinu et al., 2020). Motion capture systems, force platforms, and computational simulations have been employed to quantify the kinetic and kinematic variables in the cross-punch, yielding insights into optimal force transmission and power generation (Smith et al., 2016; Dinu and Louis, 2020; Dinu et al, 2020).

The hook punch, with its curved path, necessitates precise orchestration of hip rotation, shoulder movement, and arm swing. The hook punch, on the other hand, requires a more pronounced trunk rotation, which is a defining characteristic of this punch. The intense curvilinear rotation adds a lateral component to the punch, making it effective for targeting the sides of the opponent's head or body (Dinu and Louis, 2020; Dinu et al., 2020). Biomechanical investigations have emphasised the role of angular momentum in amplifying force transmission during the hook punch (Dinu and Louis, 2020; Dinu et al.l, 2020). The utilisation of biomechanical modelling techniques has facilitated the visualisation and quantification of the complex interactions driving the punch mechanics.

Figure 1: Illustration depicting the different punch variations: left hook (initial position, initiation, and completion); cross (initial position, initiation, and completion); rear hook (initial position, initiation, and completion).

2.3 DIFFERENCES IN PUNCH PERFORMANCE WITHIN SKILL LEVEL

Punch performance plays a critical role in determining a boxer's overall success throughout a bout. Although hand speed and punch precision are characteristics required for an effective punch (Piorkowski, 2011), numerous studies have shown that the major performance indicator in amateur boxing is the impact of a punch (Pierce *et al.,* 2006; Smith, 2006; El Ashker, 2011; Lenetsky *et al.,* 2013). A previous study revealed that punch performance measurements obtained via a boxing dynamometer could discriminate between the various levels of boxing skills (Smith *et al.,* 2000). According to Smith et al. (2000), when maximum punching performance values between three groups (Elite, Intermediate, and Novice) were measured using a boxing-specific dynamometer, punch impact ranked highest in the Elite group and lowest in the novice group.

Similarly, Filmonov et al. (1985) previously conducted an investigation to determine the technical variables that contribute to the delivery of cross-punch. They concluded that boxers with more experience and those with greater punch impact, such as ''knockout artists'' were better able to coordinate body segments and leg drive throughout their bouts. However, caution must be taken when interpreting the study results due to the calculating techniques used to measure segmental contributions and the kinetic value of the punch not being specified. Furthermore, the experiment's process is not detailed, making future replication impossible. Nonetheless, Smith et al. (2016) reported a similar finding, concluding that the greater forces in the rear hand resulted from greater lower-body involvement and trunk rotation. As such, it can be theorised that skilled and experienced boxers have a greater level of technique than those with less experience and skills level, owing to the more time spent learning and perfecting their craft.

2.4 MEASUREMENT OF PUNCH PERFORMANCE

Various devices and methods have been developed to accurately measure punch performance in boxing, given its significance in assessing specific qualities that influence sporting performance in combat sports (Lenetsky et al., 2013). However, the estimation of punch performance values can vary depending on the measuring instrument used. Previous studies investigating striking performances in combat sports have employed force plates, piezoelectric force transducers, and accelerometers to collect combat sports striking data (Smith et al., 2000; Atha et al., 1985; Falco et al., 2009; Mack et al., 2010; Pierce et al., 2006; Loturco et al., 2016; Walilko et al., 2005). While these methods have shown good reliability, they often fail to account for the multidirectional and impact components of a punch (Smith et al., 2000). Many of these devices focus solely on force values, neglecting important factors such as power and energy, which are crucial for assessing the impact of a punch. In boxing, power plays a vital role in rendering opponents unconscious, inflicting damage, and establishing tactical advantages through defence and counter-ability (Smith et al., 2000; Smith, 2006; Piorkowski et al., 2011; Lenetsky et al., 2013). Generating high power output requires producing significant force, efficiently transferring it to the environment (e.g., opponent), and doing so at a high rate of contraction (Morin and Samozino, 2016).

Evaluating kinetic values based solely on force measurements expressed in Newton is inadequate and may lead to inaccurate and inconsistent data. The impact of a punch is determined by various factors, including maximal force, contraction velocity, and energy transfer (Walilko et al., 2005). In recent years, a commercially available device specifically designed to measure strike impact has gained recognition in research. This device calculates impact power and kinetic energy transferred during the punch (The Science - Powerkube, n.d.), which are considered essential parameters for accurately assessing the damage inflicted by a strike (Walilko et al., 2005). The Powerkube incorporates a two-grade accelerometer and software that provides real-time feedback. It measures power (maximal force multiplied by velocity) and kinetic energy in Franklin (f) units. Although the use of this device to assess kinetic values is limited (Galpin et al., 2015; Del Vecchio et al., 2019), previous studies have demonstrated its acceptable reliability and accuracy (ICC > 0.98 and TEM < 3.0%) (Del Vecchio and Stanton, 2013; Galpin et al., 2015). Therefore, this study recommends utilising the Powerkube to analyse punch characteristics, particularly impact power measured in Franklin (f) per kilogram of body mass.

Moreover, studies have indicated that punch kinetic values may differ based on the body mass of individual boxers. Since kinetic energy is directly related to a boxer's mass multiplied by their velocity, boxers with greater mass have an advantage in producing higher punch performance values (Piorkowski et al., 2011). To account for this, Chaabène et al. (2014) proposed normalising the data based on body mass and providing relative punch performance values. Normalising the data allows for profiling individuals based on punch performance scores regardless of their body mass (Jacobson et al., 2013). However, it should be noted that some studies have shown a bias toward subjects with lower body mass (Atkins, 2004). To ensure a valid comparison, the use of allometric scaling has been recommended, as it effectively eliminates the influence of body mass when comparing participants (Jaric et al., 2005).

2.5 POST-ACTIVATION POTENTIATION

2.5.1 Sports and training application of PAP

To get the most punching power at impact, high force output and punching velocity are essential. Earlier research has shown that elite boxers consistently produce greater punch characteristics such as force and velocity than non-elite boxers (Dinu and Louis, 2020). As such, boxers are constantly working to improve their punch impact to obtain greater knockout power (Cheraghi et al., 2014; Loturco et al., 2016). As a result of a punch being an explosive dynamic movement (Haff et al., 2001), employing a training method based on power development may benefit boxers. Punching power may be drastically enhanced by causing the engaged muscles to enter a potentiated state, which can be achieved by different long-term training methods like resistance training (Cheraghi et al., 2014; Loturco et al., 2016) or by improving one's skill level in that specific motion (Filimonov et al., 1985). In recent years, researchers have looked at the various methods to improve power during trunk rotation and enhance sporting performance as a result. It is possible to improve punching power over time through various training methods such as resistance training, plyometric training, or by honing a specific action to improve skill; however, as with other ballistic actions, it is also possible to improve punching power acutely through an increase in neuromuscular activity.

PAP, a phenomenon in which a maximal or sub-maximal conditioning activity is combined with an explosive movement, has been widely studied for its potential to enhance the rate of force production and power (Gourgoulis et al., 2003; McBride et al., 2005; Young et al., 1998). Extensive research in the literature has examined the influence of PAP on various explosive actions, including jumping, sprinting, and other explosive motions (Judge et al., 2016; Wilson et al., 2013; Goa et al., 2016; Dolan et al., 2017; Terraza-Rebollo and Baiget, 2019). Several studies have advocated the use of PAP as a means of optimising performance in these actions (McBride et al., 2005; Docherty and Hodgson, 2007; Farup and Sørensen, 2010; Linder et al., 2010; Batista et al., 2011; Crum et al., 2012; Dolan et al., 2017). To provide a comprehensive overview of the research conducted on PAP and its effects, Table 1 presents a summary of selected studies that investigated different PAP protocols and measured outcomes related to performance. The table includes details such as study authors, participant characteristics, specific PAP protocols employed, rest intervals, outcome measures assessed, and key findings (see Table 1). This table serves as a valuable reference to understand the diverse research conducted in the field of PAP and its implications for optimising performance in explosive actions.

Table 1: Summary of Studies on Post Activation Potentiation (PAP) Protocols and Performance Outcomes.

Study	Participants	PAP Protocol	Rest Interval	Outcome Measures	Findings
Gourgoulis et al., 2003	20 physical active men	Perform half squats at different intensities	5 minutes	Mean vertical jump	The PAP led to a 2.39% increase in mean vertical jump. Stronger individuals improved their jump by 4.01% compared to 0.42% for weaker individuals.
McBride et al., 2005	15 NCAA Division III football players	Heavy loaded squat, loaded countermovement jump, control	4 minutes	Timed 40-m dash	Performing heavy-loaded squats resulted in a 0.87% faster 40-m dash. No significant differences were observed in the split times for the 10-m or 30-m distances.
Farup and Sørensen, 2010	Eight strength-trained male athletes	Isometric maximal voluntary contraction, bench throws	5 minutes	Isometric rate of force development, maximal power	A significant decrease in isometric rate of force development was observed after the intervention, but no difference in maximal power from pre to post.
Linder et al., 2010	Twelve collegiate women	Control, half squat	9 minutes	Timed 100-m track sprint	PAP protocol resulted in a significant improvement of 0.19 seconds in the 100-m track sprint. No significant differences were found in the control group.

Study	Participants	PAP Protocol	Rest Interval	Outcome Measures	Findings
Batista et al., 2011	Twenty-three male participants	Isometric contractions on the leg press exercise	4 minutes	Countermovement jump height and take-off velocity	No significant differences were observed in countermovement jump height or take-off velocity among the groups after any of the conditioning activity protocols. However, individual analysis revealed some subjects experienced increased performance in response to the conditioning activity.
Crum et al., 2012	Twenty men	Concentric-only quarter back squat at different loads	0.5, 3, 5, 10, and 15 minutes	Displacement, peak power output, peak force, rate of force development during countermovement vertical jumps	No significant differences in any of the performance measures during the countermovement vertical jumps between the control condition and the two different loads. However, 48% of the subjects demonstrated some degree of potentiation at 30 seconds after completing the 65POT trial.
Judge et al., 2016	41 male NCAA Division I track and field athletes	Overhead back shotput weight at heavy, light, and control	3 minutes minimum	Mean distance of an overhead back shotput throw	Heavy shotput warm-up yielded the highest mean performance across the three attempts.
Terraza-Rebollo and Baiget, 2019	15 competition tennis players	Bench press, half squat, bench press	0 minutes,	Serve velocity and accuracy	No significant differences were observed in ball velocity and accuracy after each recovery time and exercise.

Study	Participants	PAP Protocol	Rest Interval	Outcome Measures	Findings
		+ half squat, control	5 minutes, 10 minutes, 15 minutes		
Dolan et al., 2017	13 NCAA Division I track and field athletes	Dynamic warm-up, dynamic warm-up followed by hang clean and jerks	8 minutes	Shot put distance	Shot put throws were 3.6% higher following the PAP conditioning activity compared to non-PAP throws.
Penichet-Tomas et al., 2021 (Abstract)	7 male rowing athletes	Rowing-specific PAP protocol vs. general resistance training protocol	6 minutes	Power output, number of strokes, strokes per minute	Rowing-specific PAP protocol resulted in significant differences and extremely large effect sizes in average power output, number of strokes, and strokes per minute.

While these studies offer valuable insights into the effects of various conditioning activities on performance, it is noteworthy that there is a limited number of studies that specifically investigate the impact of PAP protocols on striking performance, such as punching in combat sports. To the best of my knowledge, the research presented in this thesis contributes to filling this gap in the literature by examining the influence of sports-specific trunk rotational movement patterns on punch performance in boxing.

PAP has gained a great deal of attention in the field of strength and conditioning during the past two decades, mostly because of its capacity to increase explosive power in athletes. Several attempts have been made throughout the years to determine whether PAP has any benefit in terms of performance increases (Ebben et al., 1999; Carter and Greenwood, 2014; Cavaco et al., 2014; Lim and Barley, 2016). Previous research by Penichet-Tomas et al. (2021) examined the effects of various PAP protocols (Rowing-specific vs. general resistance training) on the rowing performance of seven rowing athletes. Results found that when rowing-specific protocols were used, significant differences with an extremely large effect size in average power output across multiple stages were recorded. Furthermore, although no significant difference was found in maximal power, higher score values and a very large effect size were observed in the Sport-specific protocol (Penichet-Tomas et al., 2021). The research carried out by Judge et al. (2016), in which they studied forty-one collegiate track and field shotput players during PAP procedures, is another example. Athletes were divided into three different warm-up groups, each of which used a different shop put weight to warm up (control, heavy and light). In comparison of the heavy shotput warm-up condition to the control and light conditions, statistically significant differences were identified, with the heavy shotput group registering a 1.5 % greater gain in performance compared to the control and light shotput groups. This suggests that utilising a heavy shotput during warm-up may evoke PAP.

However, when PAP procedures were adopted to study the effect of PAP on serving velocity and accuracy in young competitive tennis players, Terraza-Rebollo and

Baiget (2019) found no difference in ball velocity or accuracy. One of the reasons for this may be due to the protocol utilising general resistance training exercises as opposed to sports-specific. Tennis' biomechanics follows a proximal to distal throw-like motion similar to those found in boxing, and so for exercise to be termed specific, it should follow a pattern of the kinetic chain similar to those shown in boxing. The contrasting results obtained by the above-mentioned studies (Judge et al., 2016; Terraza-Rebollo and Baiget, 2019; Penichet-Tomas et al., 2021) and others found in the literature (Duthie et al., 2002; Chiu et al., 2003) may be due to the influence of the parameters which contribute to the effectiveness of PAP. As such, practitioners must ensure that the method used to induce PAP must be individualised based on the participants conditioning background.

Research on Post Activation Potentiation (PAP) has shown its potential to enhance explosive power in athletes, primarily in jumping, and sprinting (Ebben et al., 1999; Carter and Greenwood, 2014; Cavaco et al., 2014; Lim and Barley, 2016) . However, there is limited exploration of PAP's effects on sports-specific skills beyond these measures. The specificity of conditioning activities and equipment limitations may contribute to variable results in different studies. As such, PAP's broader applicability in sports performance enhancement remains a topic for further investigation.

2.5.2 Physiology of PAP

Although the underlying physiological mechanisms of PAP are not fully understood, there are several proposed explanations. One potential mechanism is the phosphorylation of myosin regulatory light chains, which may contribute to muscle potentiation. During voluntary muscle contractions induced by the conditioning activity, myosin light chains are phosphorylated, increasing the sensitivity of actin and myosin proteins to calcium ion availability (Hodgson et al., 2005). This heightened sensitivity to calcium ions may lead to increased twitch force and the speed at which force is generated. Additionally, the increased neural activity during a maximal or near-maximal contraction may enhance the capacity to recruit and synchronise motor units for subsequent athletic activities, contributing to potentiation (Baker, 2001).

Another factor that may influence PAP is the type of muscle fibers involved. Type II muscle fibers tend to show higher levels of phosphorylation compared to type I muscle fibers (Hamada et al., 2003), indicating that individuals with a higher proportion of type II fibers, such as power and strength athletes, may experience a greater level of potentiation (Tillin and Bishop, 2009). Furthermore, it is suggested that PAP may be influenced by the lessening of inhibition from the Golgi tendon organ, which contributes to the neuronal component of PAP (Baker, 2001).
In addition to muscle fiber type and neural factors, the muscle's pennation angle is also believed to play a role in PAP. The pennation angle describes the alignment of muscle fibers with respect to bone and connective tissue, influencing the transmission of force from muscles to tendons and bones (Tillin and Bishop, 2009), with a lower pennation angle thought to have a stronger influence on PAP.

2.5.3 Recovery Time and Intensity

In order to induce PAP, a maximal or submaximal resistance exercise must be performed prior to the plyometric movement. For this reason, it is recommended to take a sufficient amount of time to recover before performing an explosive action (Rassier and MacIntosh, 2000). However, if the rest interval is prolonged for an extended period of time, potentiation may be lost, resulting in a reduction in the performance benefit gained as a result. A variety of recommendations have been provided in the literature regarding an efficient rest period, with a meta-analysis conducted by Wilson et al. (2013) discovering 7-10 minutes to be the optimal rest period between fatigue and potentiation. Seitz and Half (2016) also found that the greatest effect of PAP was seen after a rest interval of 5–7 minutes (ES = 0.49) and over 8 minutes (ES = 0.44) as opposed to those seen in 3-4 minutes (ES=0.17). Kilduff et al. (2008) also found that following 8 minutes of a recovery period between the conditioning activity and countermovement jumps, a significant jump height increase of 4.9% was observed, supporting the claim of previous research suggesting an optimal rest period of 5-10 minutes (Wilson et al., 2013; Seitz and Half, 2016).

Previous research by Aandahl et al. (2018) found improvements in roundhouse kick velocity in kickboxing and taekwondo athletes after participants were given 5-8 minutes of recovery time subsequent to 10 kicks with an elastic band. However, it is important to note that the intensity of the elastic band was measured by quantifying the tension or force applied to the tube using a load cell. The load cell is a device that measures the force applied to it. In this case, it was used to quantify the tension or resistance level of the elastic tube. By measuring the force exerted on the tube, the researchers were able to determine the intensity of the exercise based on the level of resistance provided by the tube. In other PAP research, intensity is typically measured using a percentages of one-repetition maximum (1RM) or velocity-based measurements.

The choice of intensity measurement method in PAP research is crucial as it directly influences the training stimulus applied to participants. Different methods can lead to variations in the actual intensity experienced by participants, potentially impacting the magnitude of the PAP response observed. Several studies have investigated the impact of intensity in PAP warm-up protocols. For example, Baker (2003) observed a 4.5% increase in power output during bench press throws when rugby league players performed a warm-up protocol with moderate intensity (65% of 1RM). Similarly, Dolan et al. (2017) found a significant increase of 3.6% in shotput throws after a clean and jerk PAP warm-up using 80% of 1RM. Wilson et al. (2013) suggested that a moderate load intensity between 60-84% of 1RM should be used to improve performance variables through PAP. Therefore, selecting a standardised and accurate intensity measurement method is crucial for ensuring consistent and comparable results in PAP research.

In conclusion, The optimal rest interval for inducing PAP appears to fall within the range of 5-10 minutes, with research suggesting that this duration is most effective in maximising the performance benefits of PAP (Wilson et al., 2013; Seitz and Half, 2016; Kilduff et al., 2008). The choice of intensity measurement method in PAP research is a critical factor, and it can significantly impact the training stimulus applied to participants. Studies have shown that moderate intensity is effective in eliciting PAP responses (Baker, 2003; Dolan et al., 2017; Wilson et al., 2013). However, the method used to measure intensity should be standardised to ensure consistent and comparable results across PAP protocols. Understanding the interplay between recovery time and intensity measurement is essential for designing effective PAP warm-up protocols in sports like boxing, where explosive power and force production are crucial for success.

2.5.4 Training experience and competitive level

Training status and competitive level have been found to influence the magnitude of the performance improvement elicited by post-activation potentiation (PAP) (Chiu et al., 2003; Robbins, 2005; Rixon et al., 2007; Stone et al., 2008; Wilson et al., 2013; Santos et al., 2016). In a meta-analysis by Wilson et al. (2013), it was determined that training status had a significant effect on PAP. Athletes with 3 years or more of experience (ES=0.81) showed a greater response compared to trained (ES=0.28) and untrained (ES=0.14) groups. However, when participants with only 1 year or less of resistance training experience were used, no statistical significance was found in countermovement jumps (Robbins and Docherty, 2005).

Chiu et al. (2003) conducted an investigation to determine if resistance training experience influenced the effect of PAP on performance. They found that force and power parameters were significantly higher in the more experienced group compared to the less experienced group. These findings suggest that PAP is more likely to occur in experienced athletes compared to less experienced individuals. It can be concluded that athletes familiar with resistance exercise are capable of optimising PAP while minimising fatigue effects. Furthermore, Sanchez et al. (2018) compared two groups of soccer players at different competitive levels (national vs. regional). They found significant improvements in repeated sprint ability in the national level group (fastest sprint: ES=1.5; average sprint speed: ES=1.3) compared to the regional level group (fastest sprint: ES=0.2; average sprint speed: ES=0.2). This suggests that athletes with more resistance training experience and those competing at a higher level have a higher sensitivity to PAP compared to those with less experience and competing at a lower level.

Training experience and competitive level play crucial roles in the response to PAP (Wilson et al., 2013; Santos et al., 2016). Research indicates that individuals with more extensive resistance training experience tend to exhibit a greater response to PAP, optimising performance while minimizing fatigue effects (Wilson et al., 2013; Robbins and Docherty, 2005). Additionally, athletes competing at higher levels show a higher sensitivity to PAP compared to their counterparts at lower competitive levels (Sanchez et al., 2018). However, the influence of resistance training experience and competitive level on PAP responses is a complex interplay that requires further investigation to fully understand its intricacies and implications for sports performance.

2.6 GENERAL VS. SPECIFIC RESISTANCE TRAINING

It is widely accepted that boxing success relies on the ability to generate high levels of power and force (Pierce et al., 2006; Smith, 2006; Lenetsky et al., 2013). To improve these kinetic characteristics, specific training regimes are crucial. Strength training exercises can be categorised as general (non-specific) or sport-specific based on their neural adaptations, similarity to sport movement patterns, and intermuscular coordination (Young, 2006). General strength exercises aim to develop a foundation by enhancing force production capabilities in specific muscle areas, increasing total body mass, reducing the risk of sports injuries, and improving core stability (Young, 2006). However, the use of general strength exercises may hinder sports performance improvement as they fail to replicate the movement patterns, joint angles, range of motion, and contraction velocities of actual sports actions (Morrissey et al., 1995; Young, 2006).

Sports-specific exercises closely resemble those performed in a particular sport and are considered more transferable for training effects (Bompa and Haff, 2019). Biomechanical specificity should guide exercise selection for strength and power training in order to replicate the mechanics and velocities of game-related actions (Gamble, 2016). Therefore, it is hypothesised that strength training activities with high mechanical specificity to boxing movements are beneficial for developing power in boxers.

When considering PAP, it is important to account for the specificity of the conditioning activity in relation to the primary activity. Previous studies have utilised

CAs that do not biomechanically resemble the ballistic actions paired with PAP in the specific sport (McBride et al., 2005; Linder et al., 2010; Dolan et al., 2017; Terraza-Rebollo and Baiget, 2019). For example, squatting to improve sprint time or bench pressing to enhance bench throws. However, there is limited research evaluating the effects of PAP using boxing-specific movement patterns. Penichet-Tomas et al. (2021) conducted a study investigating the effect of PAP on rowing performance using both sport-specific (rowing ergometer) and general resistance training (half squat and bench pull exercises) protocols. The study found that the sport-specific protocol resulted in significantly greater power output (ES=0.98) compared to the general resistance protocol, supporting the idea that sport-specific PAP protocols elicit a more pronounced PAP response.

Studies like the one by Aandahl et al. (2018), which explored whether roundhouse kick with elastic resistance band during warm-up could initiate PAP, provide valuable insights into the impact of sport-specific rotational movements on eliciting a PAP response. Similarly, research by Keogh et al. (2009) in golf highlighted the strong correlation between golf-specific cable woodchop exercises and clubhead speed. Given the similarities in the segmental interactions between rotational movements in golf, kickboxing and boxing, it can be inferred that a boxing-specific PAP protocol incorporating rotational exercises may have a positive effect on punch performance. However, to date, there is a lack of research specifically investigating the potential benefits of rotational PAP protocols in boxing.

In summary, it is widely acknowledged that power and force generation are pivotal for success in boxing (Pierce et al., 2006; Smith, 2006; Lenetsky et al., 2013). Training specificity plays a critical role in optimising these kinetic characteristics. While general strength exercises have their merits, they may fall short in replicating the biomechanics of sports movements (Morrissey et al., 1995; Young, 2006). On the other hand, sport-specific exercises closely mimic the demands of sports actions, potentially offering more transferable training effects (Bompa and Haff, 2019). Notably, there is limited research investigating the effects of PAP using boxing-specific movement patterns, despite the potential benefits shown in other sports such as kickboxing and golf (Aandahl et al., 2018; Keogh et al., 2009). Therefore, the extent to which incorporating rotational movements into PAP warm-up protocols can enhance punch impact power and overall boxing performance remains a subject requiring further exploration. Such research could significantly enhance our understanding of PAP in striking sports and contribute valuable insights to the development of tailored training regimens for boxers.

2.7 ELASTIC RESISTANCE BAND

The use of equipment during general resistance training exercises to elicit PAP is not logistically feasible during pre-bout warm-up due to the limited space afforded within the warm-up area of competition in boxing. It is therefore necessary to utilise practical equipment with a high degree of portability but also facilitate the augmentation of PAP-induced performance improvements. In boxing and similar combat sports, Power training is generally incorporated via the use of medicine balls, barbells, kettlebells and elastic resistance bands to allow athletes to dynamically apply force and power on an item across a wide range of motion (Markovic et al., 2016; Del Vecchio et al., 2019). It was previously suggested that the use of an elastic resistance band might elicit improvement in punch performance (Markovic et al., 2016). elastic resistance band may be used to provide resistance in order to facilitate movements across the full range of motion with velocity and force-generating characteristics comparable to those seen in sports (Janusevicius et al., 2017). Training with increased resistance in a way comparable to the competition effort is vital as an athlete with high maximal strength, but poor power will be at a disadvantage when compared to an athlete with moderate absolute strength but high power. Using resistance bands as part of PAP warm-up procedures has been proven to enhance sports-specific activities. Aandahl et al. (2018) discovered that performing a roundhouse kick against an elastic resistance band during a PAP warm-up protocol resulted in improved kicking performance. Similarly, recent research by Lum (2019) found that warm-up protocols with elastic resistance band augmented a greater PAP response on judo sport-specific performance than general resistance warm-up protocols.

While elastic resistance bands offer a lightweight and mobile option to add load pre-event and elicit PAP, there can be some limitations and potential flaws associated with seeking convenience. One limitation is the potential lack of direct correlation between the resistance provided by elastic resistance bands and traditional loading measures such as 1RM (Nyberg et al., 2014). This can lead to a disconnect between elastic resistance band research and loading protocols commonly used for PAP response. To address this issue and enhance the standardisation of elastic resistance band research, using elastic resistance bands with a specified tensile strength in kg provides a more accurate measure of resistance (Mcmaster et al., 2010). This approach allows for a better understanding of the relative intensity of elastic resistance bands compared to traditional loading methods (Nyberg et al., 2014). By incorporating the tensile strength, researchers can establish a standardised measure that aligns elastic resistance band resistance more closely with traditional resistance training practices. By utilising elastic resistance bands with known tensile strength, researchers can provide a more standardised and precise measure of resistance (Nyberg et al., 2014). This allows for better comparisons between studies and enhances the applicability of elastic resistance bands in PAP protocols. Additionally, this approach facilitates the development of guidelines for practitioners to select elastic resistance bands based on the desired resistance level, ensuring more consistent and effective training outcomes.

The use of elastic resistance bands in pre-bout warm-up procedures has shown promise in eliciting PAP responses and enhancing sports-specific performance, particularly in combat sports (Markovic et al., 2016; Del Vecchio et al., 2019). elastic resistance bands offer a portable and practical solution for athletes to apply resistance across a full range of motion, closely resembling the demands of competition. However, there is a need for standardisation in elastic resistance band research, particularly in terms of tensile strength, to align with traditional loading methods and improve consistency across studies. This standardisation will not only enhance our understanding of elastic resistance band resistance but also provide practitioners with clear guidelines for selecting elastic resistance bands based on desired resistance levels, ultimately optimising their application in PAP protocols for boxing and similar sports.

2.8 EXERCISE SPECIFICITY

When developing a PAP protocol, it's crucial to keep in mind the specificity of the conditioning exercise. According to Hodgson et al. (2005), the muscles utilised in the conditioning contraction should be as similar as possible to the muscles used in the sporting action. Previous studies have shown that PAP has greater benefits when a loaded conditioning activity is followed by an explosive action of a similar movement pattern and range of motion (Yetter and Moir, 2008; Crewther et al., 2011; Esformes et al., 2013; Whelan et al., 2014). Recently, a research done by Zemková et al. (2017) examined the standing cable woodchop as a means of evaluating and measuring maximum trunk power, and discovered that the approach was a reliable tool for measuring power. This may indicate that the woodchop is an excellent instrument for eliciting power through the trunk and, as a result, improving momentum throughout the kinetic chain. However, it is important to note that this study focused on assessing muscle power and did not directly investigate the PAP effect or its transferability to punch performance. Further research is needed to examine the specific PAP effects of the standing cable wood chop exercise on punch performance in boxing.

The Woodchop is a field test that appears identical to the hook punch in that it replicates the punch's movement pattern, range of motion, joint angles, and velocity. Keogh et al. (2009) evaluated the anthropometric profile, flexibility, muscular strength, and endurance of twenty male golfers in order to determine the relationship between kinanthropometric measures and clubhead velocity; and determine whether these measures could distinguish between low- (higher skill level) and high-handicap (lower skill level) golfers. They discovered that a golf-specific cable woodchop had the strongest overall correlation with clubhead speed ($r = 0.70$) (Keogh et al., 2009). Compared to less skilled golfers, those with higher skill levels hit the target 115% more often and at a 12% higher clubhead velocity. In addition, the more talented golfers had a 28% greater cable woodchop strength. While these findings provide insights into the associations between these variables and golf performance, it is essential to critically evaluate the transferability of these findings to the context of boxing and the specific PAP effects on punch impact power. Due to its throw-like mechanics and ability to transfer momentum via the kinetic chain from proximal to distal body segments, it can be said that the golf swing produces similar segment interactions as those seen in boxing punches. This demonstrates that a woodchop is not only an excellent method of eliciting power through trunk rotation to increase punching power but also may be used during PAP protocol in order to induce greater punch performance. To date, no research has looked at the effect of PAP on punch impact power using a trunk rotational movement pattern similar to boxing through the use of an elastic resistance band woodchop.

Previously, a study by Ab Razak et al. (2018) examined the effect of hand grip strength training and trunk rotation strength training via Woodchop conditioning activity on throwing ball velocity among female collegiate softball players. The results showed that both hand grip strength training and trunk rotation strength training significantly improved throwing ball velocity compared to basic strength training alone. However, it is important to note that this study focused on softball players and throwing ball velocity, rather than the specific context of boxing and punch impact power. Further research is needed to investigate the direct impact of trunk rotation strength training, such as the wood chop exercise, on PAP warm-up effects in punch performance. There is currently no study demonstrating that trunk rotational activity such as woodchop may be utilised to induce a PAP warm-up effect in punch performance. Transferring muscular forces from lower to upper extremities is made possible by a rotation of the trunk. There are several examples of this in sports like the javelin and tennis, as well as in kickboxing and boxing, where explosive movement patterns are used. As a result, there were two objectives for this study. The initial goal was to determine whether a boxing-specific conditioning activity combined with an elastic resistance band could elicit a potentiation effect during a warm-up in order to improve punching performance in participants. Secondly, this experiment sought to investigate whether or not the characteristics of participants, such as their training experience and competitive level, could have an impact on the extent to which potentiation takes place.

In conclusion, the specificity of the conditioning activity plays a crucial role in the effectiveness of a PAP protocol. Existing literature suggests that PAP protocols have greater benefits when the conditioning exercise closely mimics the movement pattern, range of motion, joint angles, and velocity of the subsequent sporting action (Hodgson et al., 2005; Yetter and Moir, 2008; Crewther et al., 2011; Esformes et al., 2013; Whelan et al., 2014). While studies have explored exercises such as the standing cable woodchop and their potential for measuring muscle power (Zemková et al., 2017), more research is needed to directly investigate the PAP effects of exercises like the woodchop on punch performance in boxing. Additionally, findings from other sports, such as golf, demonstrate the positive impact of a sport-specific cable woodchop exercise on performance-related variables (Keogh et al., 2009). However, the transferability of these findings to boxing and the specific PAP effects on punch impact power need further exploration. Although studies like the one by Ab Razak et al. (2018) have examined the impact of trunk rotation strength training on performance in different sports, including softball, there is a need for research specifically focused on the boxing context to assess the direct PAP warm-up effects on punch performance. Thus, the potential benefits of exercises like the woodchop in PAP protocols for boxing remain an area requiring further investigation.

2.9 SUMMARY AND IMPLICATIONS

Overall, the literature seems to agree on the presence of a potentiation effect as a result of warm-up protocols; thus, sporting actions requiring substantial power output can be augmented as a result of muscular contraction derived from a conditioning activity. Although the mechanism has been attributed to numerous physiological responses, it is suggested that the physiological responses are more likely due to 1) Actin and myosin proteins being made increasingly sensitive to Calcium ions+ availability by the phosphorylation of myosin light chains, 2) the increase acute motor-neuron pool excitability as a result of the conditioning activity, and 3) the change in Pennation angle of the muscle fibres. Nevertheless, multiple factors influence an individual's ability to benefit from PAP. One such factor is the characteristics of participants, with the magnitude of the PAP effect influenced by resistance training experience, strength level, competitive level and skill level. Numerous research has shown that more experienced, stronger, and more skilled athletes have a greater capacity to elicit a PAP response (Chiu et al., 2003, Koch et al., 2003, Wilson et al., 2013, Seitz et al., 2014). This may be attributable to the fact that athletes with greater training experience are more fatigue-resistant than those with less training experience (Wilson et al., 2013). As a consequence, it can be assumed that PAP is more evident in those considered highly trained.

The effect of PAP can also be altered by modifying the intensity, rest period, and the conditioning activity type. PAP-induced performance improvements are dependent on the rest period between the conditioning activity and sporting activities, and in order to enhance performance, it is vital to choose the appropriate rest period during which the muscle has partially recuperated from fatigue but are still potentiated. Several studies have found a potentiation effect when using various rest periods; however, 7-10 minutes has been found to be the most optimal rest duration between fatigue and potentiation (Wilson et al., 2013). With regards to the intensity, If the level of effort is too low, the PAP response may not be strong enough to produce potentiation, whilst too high of intensity may result in a greater level of fatigue. There are disparities in the literature on the appropriate intensity level to maximise a PAP response. However, a meta-analysis whereby multiple scientific studies were assed found that highly trained athletes performing PAP protocols consisting of a sport-specific conditioning activity with moderate intensity (60-84% of 1RM) are more likely to elicit muscle potentiation at a greater magnitude than performing a conditioning activity at a lower and higher intensity (Wilson et al., 2013)

A movement sequence specific to that of sporting activities should be adopted during the conditioning activity due to prior research showing greater potentiation when a biomechanically similar conditioning activity is paired with explosive action (Esformes et al., 2013; Whelan et al., 2014; Aandahl et al., 2018; Lum, 2019). The cable woodchop is a conditioning activity that has been shown to increase golf wing performance during PAP due to its similar movement pattern. Given the similarity of the golf swing and boxing punch, using a woodchop as a conditioning activity during PAP may generate a PAP response.

While previous studies have successfully used traditional strength training equipment to induce PAP in several sports, these methods may lack practical efficiency and portability for warm-up purposes at competition venues. Therefore, implementing a PAP protocol using elastic resistance may offer a more convenient and transportable option. However, to the best of the author's knowledge, no research has explored the effect of an elastic resistance band conditioning activity in inducing PAP during punch performance. It would be beneficial to investigate whether a boxing-specific conditioning activity using elastic resistance band can effectively induce PAP and explore the potential influence of training experience and competitive level on the magnitude of the PAP response

In summary, the literature highlights the presence of a potentiation effect through warm-up protocols, with various physiological mechanisms implicated (Baker, 2001; Hamada et al., 2003; Hodgson et al., 2005; Tillin and Bishop, 2009). The ability to harness this effect depends on individual characteristics, including resistance training experience, strength levels, and competitive skill (Chiu et al., 2003, Koch et al., 2003, Wilson et al., 2013, Seitz et al., 2014). Well-trained athletes appear to exhibit a greater capacity for PAP response, potentially due to their increased resistance to fatigue. The intensity and rest period between the conditioning activity and subsequent performance play crucial roles, with moderate intensity and optimal rest periods of 7-10 minutes enhancing the PAP response (Wilson et al., 2013). Additionally, the specificity of the conditioning activity, particularly in replicating biomechanical similarities to the sporting action, contributes to the magnitude of the potentiation. Notably, the use of elastic resistance bands as a conditioning activity for PAP in boxing remains unexplored.

In light of this, three hypotheses can be formulated: 1) There is a significant difference in PAP-induced punch performance improvements among participants following a elastic resistance band woodchop conditioning activity; 2) Differences in participants competitive level will result in varied PAP responses, with participants competing in higher level competitions demonstrating a more pronounced effect; 3) Variances in training experience will influence the extent of the PAP response, with those more experienced in resistance training exhibiting a greater enhancement in punch performance. These hypotheses form the basis for future research aimed at advancing our understanding of PAP and its practical applications in boxing and other combat sports.

Chapter 3: Methods

3.1 PARTICIPANTS

Fifty-three competitive amateur boxers (age = 21.8 ± 4.7 years, height = 1.77 ± 00.8 m, body mass = 75.8 ± 15.0 kg,) were recruited from five different England Boxing-affiliated clubs allocated in the London region. Participants were recruited in person and over the phone after receiving clearance from club coaches, who served as gatekeepers. Current continuous boxing experience (≥ 2 year) and official boxing record (≥ 2 bout) were used as a selection criteria. Excluded from the research were also those with any musculoskeletal injuries or other health issues that would impede punching motion and/or torso rotation. All participants were required to have been engaged in strenuous boxing training for at least twice a week over the previous 4 months. Informed consent forms (see Appendix 1) and a Physical Activity Readiness Questionnaire (PAR-Q) (see Appendix 6) were signed by all boxers prior to participating in the study. The experiment protocol was approved by the University of East London's Ethics and Committee Board (see appendix 8) prior to commencing testing.

Table 2 presents key demographic characteristics of the participants categorised based on their competitive level and resistance training (RT) experience. The categorisation of participants serves to explore potential differences in age, body mass, and height among the subpopulations. The division of participants into these categories is essential for investigating potential associations between training background and demographic characteristics. By analysing the differences valuable insights may be gained into how competitive level and RT experience may influence the punch performance of amateur boxers.

Table 2: Demographic data

	Competitive Level		RT experience	
	Development (n=31)	Open-class (n=22)	Novice (n=36)	Advanced (n=17)
Age	20.0 ± 3.5	24.5 ± 5.0	20.0 ± 3.5	25.5 ± 4.6
Body mass (kg)	70.1 ± 11.7	85.1 ± 15.9	71.5 ± 12.2	84.8 ± 16.6
Height (m)	1.75 ± 0.08	1.80 ± 0.06	1.75 ± 00.8	1.81 ± 0.06

3.2 RESEARCH DESIGN

The study adopted a one-group pretest-posttest design to assess the changes and differences in impact power of the cross and hook punches before and after intervention

3.3 RELIABILITY

Prior studies have already established the reliability and effectiveness of the PowerKube in measuring striking impact force. This study aims to replicate and reaffirm these findings by conducting a test-retest analysis to assess the consistency and stability of the data obtained using the PowerKube.

The procedure will involve dropping a medicine ball onto the PowerKube from various heights (25cm, 50cm, 75cm, and 100cm) and with different weight levels (2kg, 3kg, and 5kg). This approach mirrors a previous study conducted by Galpin et al. (2015), which investigated the reliability of the PowerKube in measuring striking impact force. In that study, the test-retest reliability score was found to be excellent (ICC = 0.99, CV (8.0kg) = 6.01%, CV (17.9) = 4.52, CV (24.0kg) = 5.68%) (Galpin et al., 2015). Furthermore, Del Vecchio and Stanton (2013) reported similar findings regarding the reliability of the PowerKube in measuring impact force, with an ICC of 0.98 and a TEM of 3.0% (Del Vecchio and Stanton, 2013). These consistent results from previous studies underscore the PowerKube's reliability as a device for measuring impact force, and this study aims to add further confirmation to this body of evidence.

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3.4 PROCEDURE

3.4.1 Familiarisation and Warm-Up

Upon reporting for testing, participants anthropometric data were recorded. A Seca Stadiometer (Seca, Birmingham, UK) was used to measure height to the nearest 0.1 cm, with a Seca 761 Dial Scale (Seca, Birmingham, UK) used to measure body mass to the nearest 0.1 kg (Seca, Birmingham, UK). Participants performed a boxing-specific warm-up which comprised of skipping, low-intensity bodyweight exercises, and dynamic stretches. Participants were provided with a pair of 12-ounce Adidas boxing gloves and instructed to wear their own hand wraps. Participants were asked to perform all punches in their usual boxing stance (Orthodox or Southpaw). Participants were not instructed on distance and position to adapt prior to performing punch motion so as to not influence technique. The Powerkube was installed at a self-selected height perpendicular to the ground (see figure 2).

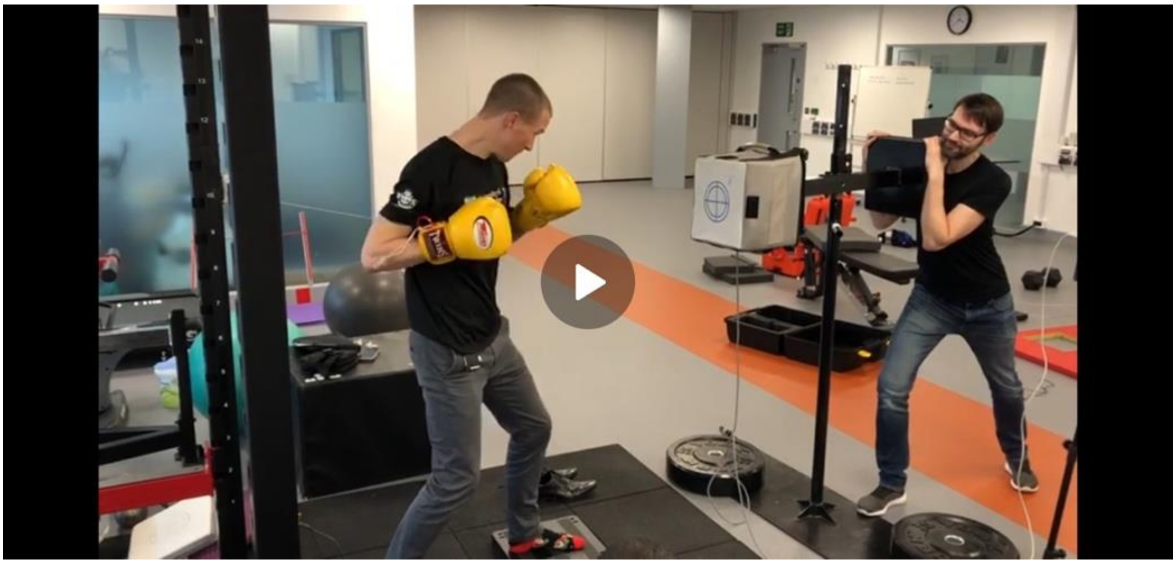

Figure 2: Powerkube positioning

Once participants completed their warm-up, a familiarisation test was conducted for the elastic resistance band woodchop conditioning activity, adopting the methods described by Zemková et al. (2017). Prior to commencing practice trials, a thorough explanation of the technique was given. In order to get more accustomed to the exercise, participants were asked to conducted slow repetitions of the movement pattern, primarily focusing on trunk rotation. The cable woodchop is an exercise that mimics the motion of chopping wood using a cable machine or resistance band. The woodchop can be done in a variety of ways, but the technique used in the current study were as follows. Resistance band were secured by wrapping the band around the hook behind participants. Gripping the handle with both hands at shoulder height and with slightly bent elbows, participants were asked to step forward away from the band hook in order to keep a constant band tension. With feet shoulder-width apart and slightly turned out, they were asked to have a slight bend of the knees and maintaining a straight back. They were then told to twist the torso horizontally across the body and rotate the rear leg whilst controlling the movement utilising the core muscles. They were then asked to perform a motion of a reverse twist and bring the band back to starting position in a control manner (see Figure 3). This was all conducted using a resistance band level of 13.6kg for 10 repetition for each side. The resistance band level of 13.6kg was chosen for the warm-up familiarisation in order to provide an appropriate level of resistance that would allow participants to gradually acclimate to the woodchop conditioning activity. This weight was selected to strike a balance between being challenging enough to engage the core muscles effectively during the warm-up and also manageable for participants to perform slow, controlled repetitions and focus on proper technique.

Figure 3: Visual representation demonstrating the Woodchop exercise utilising an elastic resistance band at three distinct phases: starting position, initiation, and completion.

Participants then performed 5 repetitions at a gradual ascending order of sets (50, 60, 70, 80, and 90% of maximum force) of all three punch variations on an impact power analysis device with instantaneous feedback (PowerKube formerly known as

Strikemate, Strike Research Limited, Norwich, United Kingdom) in order to familiarise with the protocol. The Powerkube was used to determine punch impact power and kinetic energy in a compound unit of Franklin (f).

3.4.2 Baseline Data Collection

Upon the completion of the familiarisation protocol, Participants were given a 5-minute interval before baseline test were collected. Participants then performed three rear hook punches, three Cross punches, and three frontal hook punches in a randomised sequence, with a 3-second pause proceeding each punch before and after PAP. Participants were instructed to execute each punch as fast and with as much force as possible in the target area (centre of cuboid) of the Powerkube. For the sake of the ensuing data analysis, all punches were recorded, with the highest score from each punch variant being utilised during baseline tests and post-PAP.

3.4.3 PAP inducement Conditioning activity

Proceeding this, participants were then asked to perform a elastic resistance band woodchop at 36.2kg as the PAP conditioning activity with 5 repetition at maximum speed. To ensure appropriate band tension and accommodate individual differences in strength, participants were guided to step forward away from the band hook, maintaining a constant band tension. The distance from the band hook and the tension in the band were adjusted based on each participant's individual strength level. The aim was to create enough tension in the band that was suitable for their strength level. The selection of the elastic resistance band tension level was determined by the participants' abilities.

To determine the intensity level, participants used qualitative descriptors, such as "light," "moderate," or "heavy," to describe the perceived difficulty of the warm-up exercise. These qualitative descriptors were instrumental in categorising the intensity relative to their individual strength levels. Guidelines were established based on these descriptors to assist participants in selecting an appropriate band tension. The following method was employed: During the warm-up, participants performed the exercise with the initial band tension. After completing a few repetitions, participants subjectively assessed the difficulty level. If they perceived the exercise as too easy or "light," they increased the tension of the band by stepping further away from the band hook. This adjustment aimed to provide a greater challenge and elevate the intensity. On the other hand, if participants found the exercise too difficult or "heavy," they eased the tension of the band by stepping closer to the band hook. The adjustments in band tension were made until a moderate intensity level was achieved.

3.4.4 Post-Test Data Collection

A 7-minute rest interval was then given to the participant as per Wilson et al. (2013). Upon the completion of the rest period participants were then asked to repeat the same process as during the baseline trials, with data for three punches repetition per three punch variation collected. The height and positioning of the PowerKube was personalised according to each participant's preference. However, to ensure reliability and repeatability of the tests, the positions were recorded during the initial test, and the same height was replicated in the subsequent post-test. In addition to the customised height, participants were also given the freedom to choose their preferred starting distance from the PowerKube, which had to be maintained consistently throughout the retest.

All the procedures described above were performed on the same day to minimise any potential confounding factors related to participant fatigue or daily variations in performance

3.5 STATISTICAL ANALYSIS

3.5.1 Analysis

Descriptive data will be reported as means ± SD. In order to assess if the data are normally distributed, the Shapiro–Wilk test will be performed across each variable, and the data will be considered normally distributed when the result is greater than 0.05. If the Shapiro-Wilk test reveals a normality violation ($P < 0.05$), a Wilcoxon signed-rank test will be assigned. A scaling approach based on Jaric et al., (2005) allometric normalisation will be used to reduce the discrepancies in impact power measurements caused by differences in body mass and to allow comparisons between boxers of different weight categories.

For the purposes of determining the existence of differences between pre and post-test scores for non-normal and normal distribution of data, the Wilcoxon paired test or paired sample t-test will be used. In order to compare changes in pre and post-PAP scores, data will be presented as percent differences and Effect Size (ES). In order to determine the magnitude of the difference, Cohen's D ES will be used. The ES scores will be categorised using the following criteria: Trivial (<2.0), Small (0.2-0.6), Moderate (0.6–1.2), Large (1.2-2.0), Very Large (2.0-4.0), and Extremely Large (>4.0) (Hopkins et al., 2009). In order to determine the reliability and relative variability, Coefficient of Variation (CV) (Calculated as CV = Standard Deviation / Mean) * 100), Intraclass Correlation Coefficients (ICC), and respective 90% confidence interval (CI) will be calculated (Atkinson and Nevill, 1998; Hopkins et al., 2009). Reliability will be considered acceptable at ICC >0.70 and a CV <10% (Atkinson and Nevill, 1998; Hopkins et al., 2001). SPSS ver. 26.0 (SPSS Inc., Armonk, NY, USA) will be used to examine all data.

3.5.2 Grouped Subpopulations

To categorise participants into distinct subpopulations, specific criteria were employed based on their boxing competitive level and resistance training (RT) experience. The rationale behind using these criteria lay in the recognition of prior research that underscored the significant impact of training experience and competitive level on post-activation potentiation (PAP) effects (Chiu et al., 2003; Robbins, 2005; Rixon et al., 2007; Stone et al., 2008; Wilson et al., 2013; Santos et al., 2016). By employing these criteria, the study aimed to focus the analysis on relevant subpopulations and enhance the precision of estimations. As a means of categorising participants into groups, boxing competitive level based on England Boxing (2021) Rule book will be used, with participants being assigned to either the Development or Open-class group based on the following criteria:

a. Development – A boxer who has not competed in an Open-class National Amateur Championships and/or who has not yet surpassed the upper threshold of maximum bouts for the class (20 bouts for male, and 11 for female boxers).

b. Open-class – A boxer who has competed in an Open-class National Amateur Championship and/or who has surpassed the upper threshold of maximum bouts for the class.

Resistance training experience will also be grouped into two categories, with participants with limited RT experience (< 3 years) classified as Novice, while those with higher RT status (> 3 years) will be classified as advanced. This categorisation will be adapted from the study conducted by Wilson et al. (2013).

3.6 POWER ANALYSIS

To ensure the study's statistical validity and the ability to detect meaningful effects, a power analysis was conducted. The power analysis assists in determining the probability of correctly rejecting a false null hypothesis, given the study's parameters. The parameters used for the power analysis were as follows: - Estimated effect size (Cohen's d): 0.60 (moderate effect size); - Significance level (alpha): 0.05; - Desired power: 0.80; - Sample size (N): 53. Using these parameters, the achieved power was calculated, resulting in an achieved power of approximately 0.812, which closely aligns with the desired power of 0.80. This indicates that with the chosen sample size, effect size, and significance level, the study has a strong likelihood of detecting moderate effects in the analysis. The power analysis underscores the robustness of the study's design and statistical approach, providing confidence in the study's ability to draw meaningful conclusions from the collected data.

Chapter 4: Results

4.1 RELIABILITY RESULTS

The results of the Intraclass Correlation Coefficient (ICC), Coefficient of Variation (CV%), and Standard Error of the Mean (SEM) are outlined in Table 3 for every series of 10 drops conducted at distances of 10, 20, 30, and 40 inches using 2, 3, and 5kg medicine balls.

Table 3: Intra-class correlation coefficient and coefficient of variation during three different weight variable combinations across multiple levels of Powerkube

			95% CI					
Variable	***Mean ± SD***	***ICC***	***Lower***	***Upper***	***ICC Description***	***CV%***	***CV% Interpretation***	***SEM***
2kg	1496 ± 89	.998	.994	1	Near perfect	4.92	Good Reliability	266.3 ± 124.0
3kg	2655 ± 151	.998	.997	1	Near perfect	5.77	Acceptable Reliability	411.9 ± 152.5
5kg	4891 ± 295	.999	.996	1	Near perfect	6.23	Acceptable Reliability	326.8 ± 94.9
All Variables	3014	.999	.998	1	Near perfect			

Note: ICC represents the intraclass correlation coefficient, and CV represents the coefficient of variation.

Based on the results of the test-retest reliability analysis, the PowerKube demonstrated good reliability for all variables dropped across the four distinct levels of height. The intraclass correlation coefficients (ICC) ranged from 0.91 to 0.95, indicating a high level of agreement between the repeated measurements. The coefficients of variation (CV) were below 10%, ranging from 5.21% to 6.82%, indicating low variability in the measurements. These findings suggest that the PowerKube provides consistent and stable data, meeting the criteria for reliable impact force measurement (Brady et al., 2017). These results align with similar findings in studies conducted by Galpin et al. (2015) and Del Vecchio and Stanton (2013).

4.2 MAIN RESULTS

The data provided in the study reveal that the mean (SD) impact power of all three punches increased after the warm-up and post-activation potentiation (PAP) intervention, as compared to the baseline measurements. The impact power was consistently higher for each punch variant after the warm-up. Specifically, the mean impact power for each punch across participants increased significantly, indicating a positive effect of the warm-up and PAP intervention on punch impact power. Mean Impact power for each punch across participants are provided in Table 4.

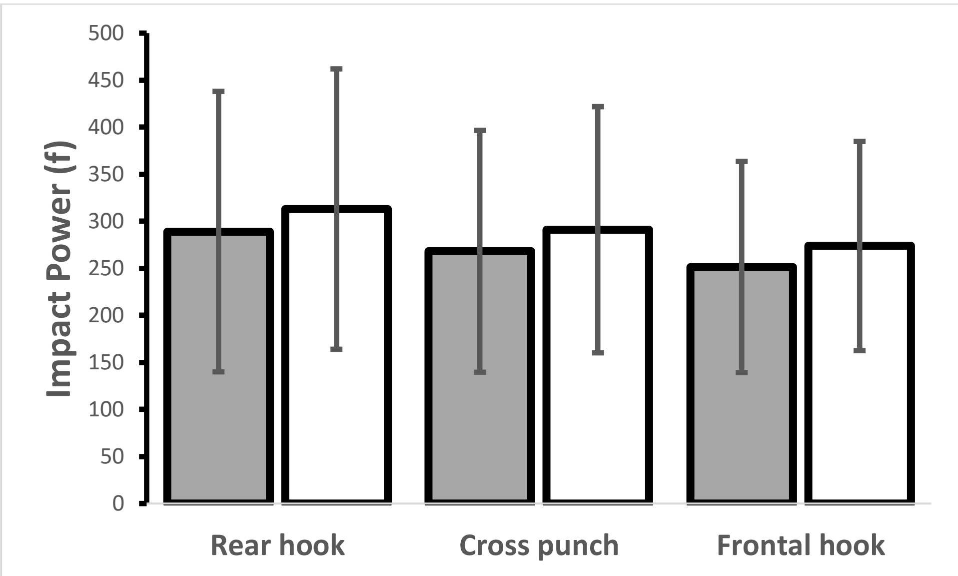

Figure 4. Difference in punch impact power during pre and post-PAP across the whole population .

The research found an increase in the mean percentage changes of all three punches, with the increase ranging from 10.65% and 12.90% between pre and post-PAP intervention. The findings of the statistical analysis indicated that there was a statistically significant difference ($P < 0.05$) in impact power between the data collected before and after the PAP in all three punches. Although significant PAP intervention effects was found across all three punches, effect size only revealed a trivial (rear hook = 0.16; Cross = 0.18; LH = 0.20) magnitude of differences between the pre and post data for each punch comparison.

Table 4 Descriptive Statistics All Participants

Impact Power (f)	Pre-test	Post-test	n	Changes		*p*	*d*	*Statistical Interpretation*
	Mean ± SD	***Mean ± SD***		***Absolute***	***Percentage***			
Rear Hook	289.1 ± 147.7	313.0 ± 149.0	53	23.9	10.65%	0.000*	0.16	Significant with a trivial Effect Size
Cross Punch	268.1 ± 128.5	291.0 ± 130.8	53	23.0	12.90%	0.006*	0.18	Significant with a trivial Effect Size
Frontal Hook	251.5 ± 112.2	273.7 ± 111.2	53	22.2	10.85%	0.000*	0.20	Significant with a trivial Effect Size

* p < .05

Using the data shown in Table 5, it can be seen that the mean (SD) impact power was higher in the post test as compared to the pre test across both the Development and Open-class groups for all three punches. All punches, with the exception of the Open-class group cross-punch (P > 0.05), showed a statistically significant difference (P < 0.05) in impact power across boxing competitive level. The effect size demonstrated that the variations between the pre and post scores in the punch variation across the Development group were of trivial magnitude. However, the magnitude of effect in the Open-class group was small in all three punches between the pre and post warm-up data.

Table 5: Descriptive Statistics of all three punch variations across different competitive level

Impact Power (f)	Pre-test	Post-test	n	Changes		*p*	*d*	*Statistical Interpretation*
	Mean ± SD	***Mean ± SD***		***Absolute***	***Percentage***			
Development Rear Hook	239.0 ± 125.1	247.2 ± 98.8	31	8.2	8.26%	0.037*	0.07	Significant with a trivial Effect Size
Open-class Rear Hook	367.1 ± 150.4	413.9 ± 159.3	22	46.8	13.90%	0.001*	0.30	Significant with a Small Effect Size
Development Cross Punch	217.3 ± 102.1	230.6 ± 87.7	31	13.3	12.18%	0.044*	0.14	Significant with a trivial Effect Size
Open-class Cross Punch	346.1 ± 129.4	383.1 ± 135.0	22	37.0	13.96%	0.058	0.28	No Significance with a Small Effect Size
Developent Frontal Hook	210.7 ± 83.8	226.4 ± 83.8	31	15.7	8.94%	0.030*	0.19	Significant with a trivial Effect Size
Open-class Frontal Hook	313.5 ± 124.5	345.4 ± 112.5	22	31.9	13.73%	0.003*	0.27	Significant with a Small Effect Size

* p < .05

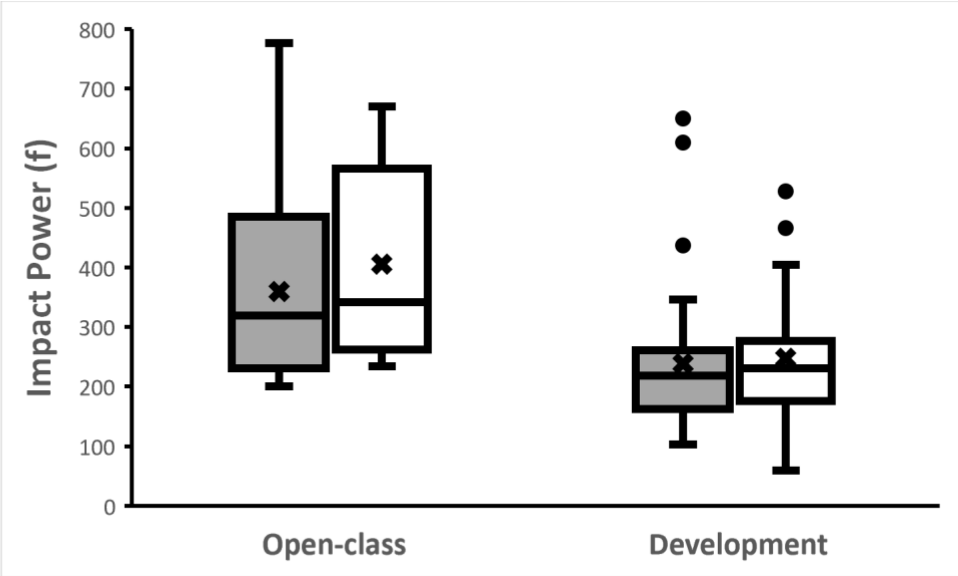

Figure 5. Difference in rear hook punching impact power during pre and post-PAP for competitive level (Open-class and Development).

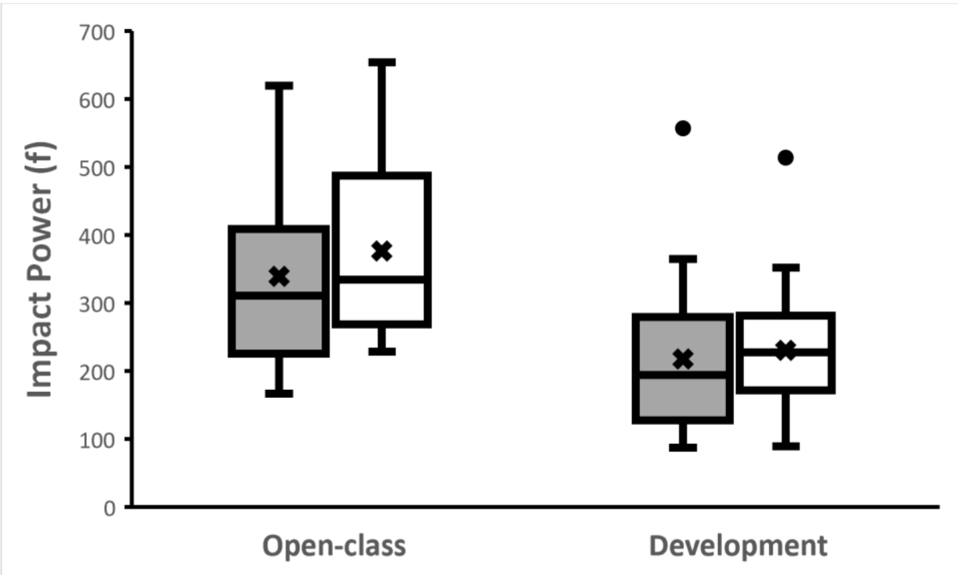

Figure 6. Difference in cross-punch punching impact power during pre and post-PAP for competitive level (Open-class and Development).

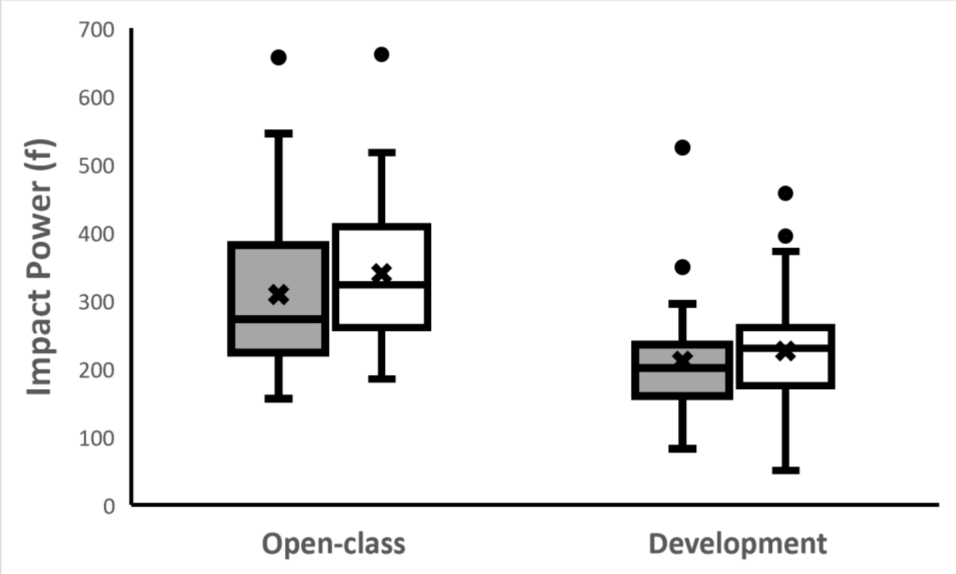

Figure 7. Difference in frontal hook punching impact power during pre and post-PAP for competitive level (Open-class and Development).

Similar to the boxing competitive level subgroup, when comparisons were made between boxers of different resistance training experience, post warm-up mean scores of all three punches increased across all groups. Rear hook and frontal hook punches from both the Novice and advanced group showed a significant difference between baseline and post-test. Although a significant difference was also found in the Novice cross-punch, no significant difference were found in the advanced group for the same punch. Within the Novice group, a trivial effect size was found in the rear hook and frontal hook punch as well as the cross-punch, whilst all three punches in the advanced group showed a small magnitude of effect.

Table 6 Descriptive Statistics Resistance Training Category:

Impact Power (f)	Pre-test *Mean* ± *SD*	Post-test *Mean* ± *SD*	n	Changes	*Percentage*	*p*	*d*	*Statistical Interpretation*
Novice Rear Hook	247.1 ± 135.2	266.3 ± 124.0	36	19.2	10.96%	0.005*	0.15	Significant difference with a trivial Effect Size
Advanced Rear Hook	378.0 ± 136.2	411.9 ± 152.5	17	33.9	10.02%	0.007*	0.23	Significant difference with a Small Effect Size
Novice Cross Punch	227.6 ± 115.2	249.5 ± 114.7	36	21.9	14.43%	0.004*	0.19	Significant difference with a trivial Effect Size
Advanced Cross Punch	353.8 ± 114.7	379.0 ± 121.4	17	25.2	9.65%	0.227	0.21	No Significant diff. with a Small effect Size
Novice Frontal Hook	237.4 ± 120.6	248.6 ± 110.6	36	11.2	7.40%	0.031*	0.10	Significant difference with a trivial effect size
Advanced Frontal Hook	281.2 ± 87.9	326.8 ± 94.9	17	45.6	18.15%	0.001*	0.45	Significant difference with a Small Effect Size

* $p < .05$

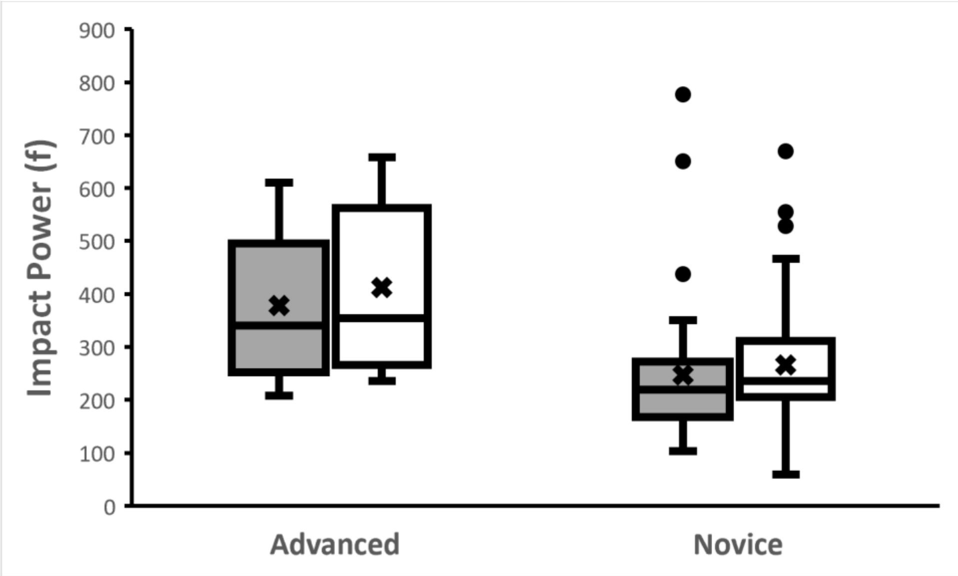

Figure 8. Difference in Rear hook punching impact power during pre and post-PAP for RT experience (advanced and novice).

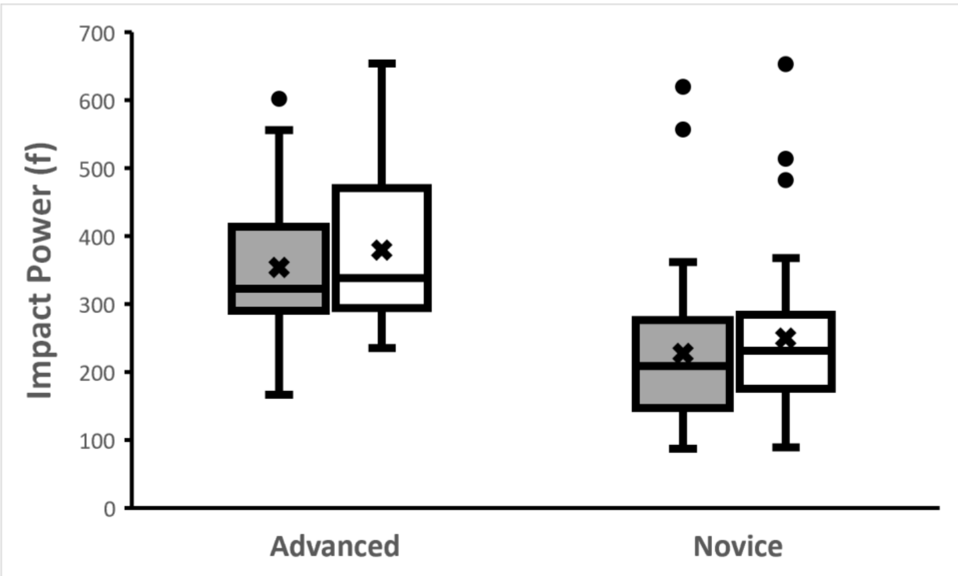

Figure 9. Difference in cross-punch punching impact power during pre and post-PAP for RT experience (advanced and novice).

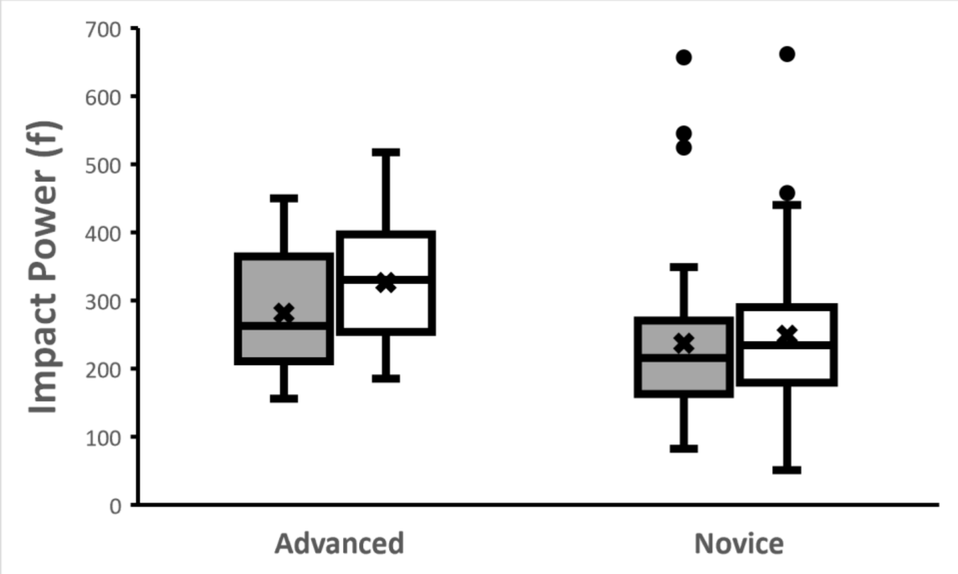

Figure 10. Difference in frontal hook punching impact power during pre and post-PAP for RT experience (advanced and novice).

Chapter 5: Discussion

This study aimed to evaluate the impact of a PAP warm-up protocol, involving a boxing-specific conditioning activity, on enhancing punch impact power.

5.1 THE EFFECT OF PUNCH PROTOCOL ON PUNCH PERFORMANCE

In the current study, the data revealed a notable trend: the implementation of a PAP protocol involving an elastic resistance band woodchop conditioning activity led to improvements in punch performance across all three punch variations. This finding is of paramount importance as it directly aligns with the main hypothesis of the study, suggesting that a boxing-specific conditioning activity like the woodchop, when combined with PAP, holds the potential to enhance punch performance significantly. However, it is essential to address the observed results in greater detail. The study indeed showed a statistically significant difference in punch impact power between the pre and post-PAP tests across all three punches. Nevertheless, the trivial effect size observed in the study suggests that while there was a statistical improvement, its practical significance may be limited. Several factors may contribute to this outcome. It is plausible that the PAP intervention had a relatively modest impact on enhancing punch performance within this specific sample. Moreover, individual variations in response to PAP, such as fatigue resistance and training experience, could have played a role in influencing the results. Existing research has indicated that factors like training experience and competitive level may influence the response to PAP, with highly trained athletes potentially exhibiting greater resistance to fatigue, which could diminish the effect of PAP on punch performance (Chiu et al., 2003; Koch et al., 2003; Wilson et al., 2013; Seitz et al., 2014). Therefore, while the results show a statistically significant difference, the trivial effect size underscores the need for further investigation to delve into the multifaceted factors that contribute to the variability in the response to PAP and its tangible impact on punch performance.

The presence of a statistical difference in punch impact power between the pre and PAP tests across all three punches signifies an improvement in punch performance.

However, the trivial effect size associated with these differences prompts a closer examination of the underlying factors influencing these results. One aspect that stands out is the substantial Standard Deviation of the mean in both the pre and post-PAP data for all three punches. This substantial variation in the data suggests that the participants' punch performance was not clustered around a single mean but rather exhibited significant dispersion.

This variability in the data could be indicative of the presence of distinct subgroups within the sample. One plausible explanation could be that factors such as competitive level and resistance training experience, which were previously identified as potential influencers of PAP response (Chiu et al., 2003; Robbins, 2005; Rixon et al., 2007; Stone et al., 2008; Wilson et al., 2013; Santos et al., 2016), have contributed to this dispersion. It is possible that these factors have led to the formation of subgroups within the sample, each with its own unique response to the PAP protocol. This could explain why we observe larger standard deviations and differences between punches, as different subgroups may respond differently to the intervention. As such, it seems justified to consider further analysis by separating the participants based on competitive level and resistance training experience. This approach could help elucidate whether specific subgroups within the sample exhibit more pronounced responses to the PAP protocol and shed light on the factors contributing to the observed variability.

5.2 PAP EFFECT OF PUNCH IMPACT POWER

In light of the substantial variation observed in the punch impact power data across all participants, it became evident that further investigation was warranted to unveil the underlying factors contributing to this variability. As such, participants were divided into subgroups, primarily based on competitive level and resistance training experience. These two factors, competitive level (categorised as Development and Open-class Group) and resistance training experience (classified as Novice and Advanced Group), were chosen due to their potential influence on the response to PAP protocols, as suggested by previous research (Chiu et al., 2003, Koch et al., 2003, Wilson et al., 2013, Seitz et al., 2014).

When an assessment of the two groups of different competitive level were separately conducted, punch impact power results demonstrated that the PAP protocols was able to elicit a positive effect punch performance effect on participants at both levels of competition (Open-class vs. Development). The data showed a significant difference and trivial effect size level for the development group in all three punches. The open-class reported a significant difference in the rear hook and frontal hook results between pre and post-test. Although no significant differences were found in the cross-punch, all three punches showed a small effect size. Furthermore, the open-class group produced greater absolute and percentage change, indicating that an elastic resistance band woodchop warm-up PAP protocol elicits a greater PAP response in the open-class group than the development group. These findings substantiate the hypothesis that competitive levels can influence PAP responses, with higher-level competitors, such as those in the Open-class group, experiencing more significant enhancements in punch performance following the PAP warm-up protocol. While the effect sizes remained small, the practical implications of these subtle changes may warrant further exploration, as they could potentially contribute to a competitive advantage in boxing

When PAP data were grouped based on RT experience, a significant difference were reported in all three punches of the novice group, whilst the advanced group rear hook and frontal hook also showed a significant difference. No significant differences were found in the cross-punch of the advanced group. The results found that all three punches of the RT Novice group displayed trivial effect size, with a small effect size exhibited on all three punch variations of the open-class. Although the advanced group had a greater absolute change in all three punches, participants in the Novice group exhibited a greater positive percentage change in both the rear hand hook and the cross-punch compared to the advanced group. However, the advanced group did show a greater percentage change in the frontal hook. The results indicate that when analysing the whole sample or dividing them into groups of competitive level and training experience, a PAP warm-up protocol with elastic resistance band woodchop may cause an increase in punch performance. Some of the results were significant with a small effect size, suggesting that there is an effect.

These results align with the hypothesis that variances in training experience influence the extent of the PAP response, with those more experienced in resistance training exhibiting a greater enhancement in punch performance compared to the Novice group. These findings emphasize the role of training experience in shaping the response to PAP and its impact on punch performance.

The significant performance improvements of punch impact power (cross-punch: 12.90%; rear hook: 10.65%; and frontal hook: 10.85%) are consistent with previous research of PAP protocols with elastic resistance band (Buttifant and Hrysomallis, 2015; Aandahl et al., 2017; Luma, 2019; Mina et al., 2019; Peng et al., 2021). In Mina et al. (2019) recent research, it was found that performing back squat exercises with free weight resistance and elastic resistance band during warm-up increased jump height by 5.3%-6.5% and peak power 4.4%-5.9%, whilst Buttifant and Hrysomallis (2015) reported improvements of 12–14% in acute power during warm-up protocols using box squats with elastic resistance band at moderate to high intensity. conditioning activity with elastic resistance band as a PAP intervention has also been shown to enhance performance in other combat sports. Lum (2019) reported a significant increase in power output when elastic resistance band judo-specific actions combined with a standing broad jump, whilst Aandahl et al. (2018) found that roundhouse kick using an elastic resistance band fastened around the ankle increased kicking velocity in Kickboxing and taekwondo athletes by 3.3%. The results found in the current research seems to suggest that using elastic resistance band during pre-competition warm-up protocol may provide an efficient method of improving muscle performance.

In previous studies, PAP protocols have mostly used free-weight as a way of stimulating a PAP effect, with limited research looking at the possible potentiating effects of elastic resistance band conditioning activity during warm-up protocols. The elastic resistance band Woodchop exercise was chosen in an effort to induce the PAP effect due to the biomechanical patterns of the movement closely resembling those seen in the hook punches. To the best of the author's knowledge, the present investigation was the first to examine whether punch impact power could be augmented as a result of a preload stimulus using an elastic resistance band .

Several theories may explain the mechanism behind the positive PAP effect observed in the current study. One may be due to the effectiveness of elastic resistance band in training the neuromuscular system in the concept of acceleration. Theoretically, using a conditioning activity with an elastic resistance band may be more effective than traditional strength exercises since performing an explosive exercise with a constant load leads to a deceleration phase after overcoming the inertia during the concentric phase of a movement, leading to a decrement in momentum (Keohane 1986). By comparison, sporting actions such as throwing and punching in boxing cause a rise in force throughout the concentric phase, resulting in greater accumulative momentum to be released to the environment (Rousanoglou et al., 2014; Watkins et al., 2021), or in the case of boxing, to the opposing opponent (Piorkowski *et al.*, 2011; Cheraghi *et al.*, 2014). elastic resistance band allows the muscles to contract throughout the range of motion, allowing for progressive overload throughout the movement as per the length-tension relationship (Kraemer et al., 2001; Wallace et al., 2006). Furthermore, it can be conjectured that the elastic resistance band may induce a PAP response due to its ability to stimulate initial preparatory muscular stiffness through neural receptors that detect the force levels, which in turn increases through activating the number of motor units recruited and/or the rate in which they fire (Baker and Newton, 2009).

Several factors influence the improved performance proceeding PAP, including recovery time, intensity, type of conditioning activity, subsequent activity, competitive level, and previous RT experience (Tillin and Bishop, 2009). The current study used an intensity of 5RM for elastic resistance band Woodchop at moderate intensity (60-84%) with a subsequent 7-minute rest interval. The improvement in punch impact power after the warm-up protocol suggests that the rest interval of 7 minutes with a moderate volume intensity was adequate to counteract the effects of fatigue. This falls in line with Wilson et al. (2013), who suggested a 7-10 minutes rest interval at moderate intensity as a way to optimally augment power output after a conditioning activity. The findings are similar to earlier research, which has shown significant improvements in power output across different explosive actions after a PAP protocol with rest periods of between 6 and 10 minutes (Esformes and Bampouras, 2013; Sue et al., 2016; Peng et al., 2021; Penichet-Tomas et al., 2021).

In that regard, a rest period close to 7 minutes at moderate intensity appears adequate as a way of augmenting potentiation.

The results found in the current research suggests that regardless of the participant's characteristics, an elastic resistance band woodchop conditioning activity can induce a PAP effect. However, the magnitude of improvement is dependent on participants competitive level and RT experience. The greater increase in muscular performance in participants of higher competitive level seen in the current study corroborates with earlier findings, who reported that athletes competing at a higher level had an increased probability of augmenting performance based on the PAP effect (Chiu et al., 2013; Seitz and Haff, 2016; Sanchez et al., 2018). A possible explanation for this is neural adaptation, as it is thought that the more highly trained athletes may have the capacity to elicit greater motor unit recruitment, degree of synchrony, and firing frequency (Chapman et al., 2008; Heise et al., 2008; Baechle and Earle, 2008; Tillin and Bishop, 2009).

In the current research, it was found that participants of the advanced group had a greater increase in punch performance when compared to those in the novice group. This falls in line with evidence from previous research who have suggested that experience lifters had a greater potentiation response than inexperienced lifters (Chiu et al., 2004; Robbins, 2005; Rixon et al., 2007; Stone et al., 2008). The current research found that participants who had three years or greater strength training experience were able to augment a greater magnitude of PAP stimulation compared to those with less than three years, falling in agreement with Wilson et al. (2013) and Santos et al. (2016) previous finding. A possible explanation for this may be that participants with more experience have a greater tolerance to fatigue due to the relationship between potentiation and fatigue. The enhancement of muscle contractile performance depends on the balance between the two factors. When fatigue is large enough to subdue potentiation, a decrease in performance may transpire; yet, if potentiation is greater, muscle performance will improve. This seems to correlate to previous studies, which reported that athletes with greater training experience were more likely to be resistant to the effects of fatigue (Kilduff et al., 2007; Wilson et al., 2013).

It had been theorised that stronger participants have a greater potentiation response due to greater strength level, with strength level being strongly linked to the magnitude of the potentiation (Hodgson et al., 2005; Robbins, 2005). Although no strength data were collected in the current research, it is reasonable to suggest that participants with experience levels of 3 years or greater in RT were stronger than those of less than three years. According to previous studies, participants who are considered stronger are more sensitive to PAP stimuli due to having a higher proportion of type II muscle fibres, muscle fibre pennation angle, and increase in Ca2+ sensitivity (Tillin and Bishop, 2009; Wilson et al., 2013; Seitz et al., 2014). Scientific evidence suggests that the pennation angle of muscle fibres decreases after a conditioning activity. Reduced pennation angle of the muscle allows for increased force transmission via the tendon and subsequently to the bone during contraction, potentially resulting in greater power output (Tillin and Bishop, 2009). It has been discovered that the pennation angle of muscle fibres changes 3-6 minutes after a voluntary contraction at maximum force. Although the changes only equate to a 1% rise in force transmission to the tendons (Mahfeld et al., 2004), it is feasible that participants muscle fibre pennation angle may also be a contributory factor to PAP.

Surprisingly, when the result of the cross-punch was compared to determine if PAP benefitted participants of different characteristics, it was revealed that only the development and Novice group had a significant improvement, with no statistical difference found in the Open-class and advanced group. It is possible that within the current research, the absence of a statistically significant increase in impact power during the cross-punch of the Open-class may be related to the difference in motion patterns between the Woodchop exercise and the cross-punch. Previously, Dinu and Louis (2020) investigated the differences in punch execution between Elite and well-trained boxers using a 3D Kinematic analysis. When body segment contribution was assessed, it was found that trunk rotational contribution was higher in well-trained boxers than the Elite boxers during the cross-punch. The conditioning activity (woodchop) used in the present study follows a movement pattern relying on trunk rotation and thus may be biomechanically different to those of the cross-punch. Thus, it can be argued that the difference in significance between the groups is as a result of the less efficient body segment contribution of a cross-punch from the Development group being more biomechanically similar to the woodchop, with the more skilled boxers utilising less trunk rotation during the movement and thus being less biomechanically identical to the conditioning activity.

Current research also found that although participants of greater competitive level and RT experience displayed a greater capacity to induce a PAP response, participants of higher competitive level showed greater percentage and absolute change in impact power in both the rear hook and cross-punch, with the advanced group reporting greater percentage and absolute change in the frontal hook. This potentially highlights that athletes competitive level is more relevant than RT experience in determining the factors which influence a PAP response.

As one of the first studies to explore the effects of PAP on punch performance using an elastic resistance band conditioning activity (woodchop) as opposed to more traditional warm-up devices (e.g., barbell) as employed in other PAP studies, numerous concerns remain unresolved as a result of this research. On the whole, this study suggests that moderate-intensity elastic resistance band woodchop can trigger an increase in punch impact power when applied as a warm-up protocol during competition. The extent of the increase may depend on the characteristics of the participants, with highly trained athletes with greater resistance training experience found to be able to exploit PAP to a greater degree. When deciding whether or not to incorporate elastic resistance band woodchop as part of a warm-up protocol, strength & conditioners and boxing coaches should individualise warm-up based on participants characteristics. Further research is required to identify the length of the induced potentiation, particularly during competition. Be that as it may, a similar study is necessary, that also should include, but not be limited to, the use of conditioning activity that is biomechanically similar to the cross-punch, an additional intervention such as a warm-up with free-weight, and the use of different rest periods to determine the optimal potentiation period.

5.3 LIMITATIONS

The current study has identified several limitations that should be carefully considered when interpreting the findings, particularly in relation to the methods employed. These limitations provide important insights for future research and highlight areas where further methodological refinement can enhance the understanding and application of post-activation potentiation (PAP) warm-up protocols in boxing. Firstly, it is crucial to acknowledge that the generalisability of the results may be limited to the specific population investigated in this study. Participants in this study had a minimum of two years of continuous boxing training experience and had competed in at least two bouts. Their training background and competitive experience may have influenced their fatigue resistance and ability to perform the conditioning activity. Therefore, caution should be exercised when extrapolating the findings to individuals with different levels of training experience or competitive backgrounds. Future research should aim to include a more diverse range of participants to provide a broader understanding of the effects of PAP protocols in different populations. Another notable limitation is the absence of a control group in the study design. The lack of a comparison group consisting of individuals without boxing training or a different warm-up protocol limits the ability to determine the specific effects of the elastic resistance band woodchop warm-up protocol on punch impact power. Including a control or comparison group would enable a more comprehensive evaluation of the benefits and limitations of the elastic resistance band woodchop warm-up protocol and its potential superiority over other warm-up methods or no warm-up at all. Future research should consider incorporating control or comparison groups to provide a more robust understanding of the effects of different warm-up strategies on punch performance.

Furthermore, the duration of the recovery period between the warm-up and punch impact tests warrants consideration. The 7-minute rest interval used in this study may not have been optimal for maximising the potentiation effect. Different rest periods following the elastic resistance band woodchop exercise should be systematically examined to determine the most effective timing for inducing and sustaining the PAP response. This will enable practitioners to design warm-up protocols that yield consistent and reliable improvements in punch performance. Future research should aim to identify the optimal rest period based on individual participant characteristics and the specific goals of the warm-up protocol. Additionally, the choice of the woodchop exercise in this study may have introduced a bias towards movements resembling the hook punches rather than the cross-punch. The biomechanical similarity between the woodchop exercise and the hook punches could have contributed to a greater potentiation effect for those specific punches. Caution should be exercised when extrapolating the findings to the cross-punch or other punch variations. Future research should explore the effects of conditioning activities that closely resemble the movement patterns of the cross-punch to determine their potential for eliciting greater PAP stimuli specific to that punch. This will provide a more comprehensive understanding of the transferability and applicability of the findings to different punches commonly used in boxing.

Moreover, the volume of the warm-up protocol used in this study, including five elastic resistance band woodchop repetitions at a moderate intensity along with three different punch variations, should be interpreted with caution. While this volume was chosen based on the study design, it is essential to recognise that increasing or decreasing the number of repetitions performed at the same intensity can significantly impact the PAP effect. Future research should carefully consider the volume and intensity of the warm-up protocol, taking into account individual participant characteristics and the desired outcomes. This will help optimise the PAP response while minimising the risk of excessive volume, which could have detrimental effects on punch performance. Finally, the study primarily focused on assessing punch impact power as the primary outcome measure. While punch impact power is an important indicator of performance in boxing, it is just one aspect of overall boxing performance. Future research should consider incorporating additional outcome measures such as punch accuracy, speed, or other relevant performance variables to provide a more comprehensive assessment of the effects of the elastic resistance band woodchop warm-up protocol on various aspects of boxing performance. This multifaceted approach will provide a more nuanced understanding of the benefits and limitations of PAP warm-up protocols in enhancing overall boxing performance.

Overall, these identified limitations underscore the importance of further methodological refinement and investigation in future studies to enhance the understanding and application of PAP warm-up protocols in boxing. By addressing these limitations and building upon the existing knowledge, researchers can provide more robust and reliable evidence to guide practitioners in developing effective warm-up strategies for improving punch performance across diverse populations.

5.4 PRACTICAL IMPLICATION

The current finding indicates that elastic resistance band Woodchop is an effective warm-up method for boxers competing at all levels of competition. The 10.65-12.90% increase in impact power seen throughout the study was most likely caused by the activation of PAP. Thus, a PAP effect was observed following an elastic resistance band Woodchop, as seen by increased muscular activity. As such, an elastic resistance band woodchop exercise may be beneficial to include in a pre-fight warm-up plan if such advantages are seen. Practitioners may benefit from these findings as they could help improve short-term performance.

Additionally, elastic resistance bands' portability makes pre-bout PAP protocol more practical. Preliminary studies should be undertaken to determine if PAP improves competitive performance, particularly when athletes are under constant pressure and fatigue. The athlete's RT experience should be considered when developing methods to stimulate PAP to augment performance. Following a series of sub-maximal conditioning activity, it appears that those with more RT experience may display a higher PAP response. It seems that a rest interval between 7-12 minutes between conditioning activity and explosive action would provide greater benefit to performance. However, while designing PAP protocol, practitioners should consider the recovery period between the conditioning activity and the sporting action per the participants RT experience. A strong body of scientific evidence suggests that fibre type and neuromuscular activation may play a role in the reported differences between responded and non-responded to the PAP effect. Research into neuromuscular characteristics like fibre type and excitability of the motor neurone pool is needed to learn more about the neuromuscular element appertaining to the strength that may influence the PAP effect.

Chapter 6: Conclusions

In conclusion, the current study demonstrated that punch performance could be acutely enhanced by post-activation potentiation (PAP). The results indicate that by using an elastic resistance band to perform a conditioning activity, PAP-induced performance can be augmented across different punch variations. In the current trials, punch impact power was increased by 10.65% in the rear hook, 12.90% in the cross-punch, and 10.85% in the frontal hook following the PAP inducing elastic resistance band Woodchop protocol. This is consistent with previous reports that PAP using elastic resistance band significantly increased performance during warm-up protocols (Buttifant and Hrysomallis, 2015; Aandahl et al., 2017; Mina et al., 2019; Peng et al., 2021). The subsequent performance improvements from PAP are likely a result of neuromuscular adaptations to muscular contraction due to the conditioning activity.

When participants were split based on the competitive level in which they compete, a significant induced PAP performance improvement was found in both the Open-class and Development group compared to baseline. However, participants competing at higher competitive levels showed greater improvements. The greater improvement in impact power from the Open-class group can be attributed to the participants in that particular group being more skilled and thus eliciting greater motor unit recruitment, synchronisation, and firing frequency. It was also found that when the participants in the current study were split into groups of Novice and Advanced RT experience, a significant difference between pre and post-impact power was revealed in all punches throughout both groups except for the cross-punch in the advanced group; However, the advanced group had a greater level of punch performance improvements (small effect size) when compared to the Novice group (trivial effect size). The link between potentiation and fatigue may explain this, with the augmentation of muscle contractile performance reliant on the balance between the two components. Stronger participants respond better to PAP stimuli owing to an increased proportion of type II muscle fibres, muscle fibre pennation angle, and Ca2+ sensitivity. Although strength levels were not quantified in the present research, it can be concluded that participants with more RT experience are more likely to be stronger than those with less experience.

The present study's findings add to the literature supporting the effect of elastic resistance band on eliciting a PAP response to enhance performance. It is the first study to observe a significant PAP effect of elastic resistance band Woodchop on punch performance improvements. Providing the basis for additional research into the effect of PAP on fibre type and the excitability of the motor neurone. The findings of the current study are consistent with previous research that has found elastic resistance band to be an effective method to induce a PAP response to improve performance. The results highlight the effectiveness of elastic resistance band as a way of eliciting PAP a response and that it is a practical method for pre-bout warm-up due to its portability. This may be particularly important for athletes and coaches alike who may not have free-weight equipment during competition. An elastic resistance band can easily be placed in a gym bag as they require minimum space, making them portable.

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Dear Andy,

Application ID: ETH2324-0076

Original application ID: ETH2122-0113

Project title: Post-activation potentiation of trunk rotational movement on punch power output in amateur boxers

Lead researcher: Dr Andy Galbraith

Researcher: Mr Lee Brown

Researcher: Mr Gary Doyle

Researcher: Dr Alireza Monajati

Researcher: Mr Silvino Domingos

Your application to Ethics and Integrity Sub-Committee (EISC) was considered on the 14th November 2023.

The decision is: **Approved**

The Committee's response is based on the protocol described in the application form and supporting documentation.

Your project has received ethical approval for 4 years from the approval date.

If you have any questions regarding this application please contact your supervisor or the administrator for the Ethics and Integrity Sub-Committee.

Approval has been given for the submitted application only and the research must be conducted accordingly.

Should you wish to make any changes in connection with this research/consultancy project you must complete 'An application for approval of an amendment to an existing application'.

The approval of the proposed research/consultancy project applies to the following site.

Project site: **UEL Docklands Campus**

Principal Investigator / Local Collaborator: Dr Andy Galbraith

Approval is given on the understanding that the UEL Code of Practice for Research and the Code of Practice for Research Ethics is adhered to.

Any adverse events or reactions that occur in connection with this research/consultancy project should be reported using the University's form for Reporting an Adverse/Serious Adverse Event/Reaction.

The University will periodically audit a random sample of approved applications for ethical approval, to ensure that the projects are conducted in compliance with the consent given by the Ethics and Integrity Sub-Committee and to the highest standards of rigour and integrity.

Please note, it is your responsibility to retain this letter for your records.

University of East London

Pioneering Futures Since 1898

With the Committee's best wishes for the success of the project.

Yours sincerely,

Fernanda Da Silva Hendriks

Administrative Officer for Research Governance

University of East London

Pioneering Futures Since 1898

Dear Andy

Application ID: ETH1819-0212

Project title: Methodological considerations to optimise the PAP effect on punching force

Lead researcher: Dr Andy Galbraith

Researcher: Mr Lee Brown

Researcher: Mr Gary Doyle

Researcher: Dr Alireza Monajati

Your application to Research, Research Degrees and Ethics Sub-Committee meeting was considered on the 2nd of October 2019.

The decision is: **Approved**

The Committee's response is based on the protocol described in the application form and supporting documentation.

Your project has received ethical approval for 4 years from the approval date.

If you have any questions regarding this application please contact your supervisor or the secretary for the Research, Research Degrees and Ethics Sub-Committee meeting.

Approval has been given for the submitted application only and the research must be conducted accordingly.

Should you wish to make any changes in connection with this research project you must complete An application for approval of an amendment to an existing application.

The approval of the proposed research applies to the following research site.

Research site: UEL Docklands Campus

Principal Investigator / Local Collaborator: Dr Andy Galbraith

Approval is given on the understanding that the UEL Code of Practice for Research and the Code of Practice for Research Ethics is adhered to.

Any adverse events or reactions that occur in connection with this research project should be reported using the University's form for Reporting an Adverse/Serious Adverse Event/Reaction.

The University will periodically audit a random sample of approved applications for ethical approval, to ensure that the research projects are conducted in compliance with the consent given by the Research Ethics Committee and to the highest standards of rigour and integrity.

Please note, it is your responsibility to retain this letter for your records.

With the Committee's best wishes for the success of the project

Yours sincerely

Docklands Campus
University Way
London E16 2RD

Stratford Campus
Water Lane
London E15 4LZ

University Square Stratford
Salway Road
London E15 1NF

+44 (0)20 8223 3000
srm@uel.ac.uk
uel.ac.uk

University of East London

Pioneering Futures Since 1898

Dear Andy

Application ID: ETH1920-0130

Original application ID: ETH1819-0212

Project title: Methodological considerations to optimise the PAP effect on punching force

Lead researcher: Dr Andy Galbraith

Researcher: Mr Lee Brown

Researcher: Mr Gary Doyle

Researcher: Dr Alireza Monajati

Your application to University Research Ethics Sub-Committee was considered on the 3rd of February 2020.

The decision is: **Approved**

The Committee's response is based on the protocol described in the application form and supporting documentation.

Your project has received ethical approval for 4 years from the approval date.

If you have any questions regarding this application please contact your supervisor or the secretary for the University Research Ethics Sub-Committee.

Approval has been given for the submitted application only and the research must be conducted accordingly.

Should you wish to make any changes in connection with this research project you must complete An application for approval of an amendment to an existing application.

The approval of the proposed research applies to the following research site.

Research site: UEL Docklands Campus

Principal Investigator / Local Collaborator: Dr Andy Galbraith

Approval is given on the understanding that the UEL Code of Practice for Research and the Code of Practice for Research Ethics is adhered to.

Any adverse events or reactions that occur in connection with this research project should be reported using the University's form for Reporting an Adverse/Serious Adverse Event/Reaction.

The University will periodically audit a random sample of approved applications for ethical approval, to ensure that the research projects are conducted in compliance with the consent given by the Research Ethics Committee and to the highest standards of rigour and integrity.

Please note, it is your responsibility to retain this letter for your records.

With the Committee's best wishes for the success of the project

Yours sincerely

Docklands Campus University Way London E16 2RD

Stratford Campus Water Lane London E15 4LZ

University Square Stratford Salway Road London E15 1NF

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University of East London
Pioneering Futures Since 1898

Dear Andy

Application ID: ETH2122-0113

Original application ID: ETH1920-0130

Project title: Methodological considerations to optimise the PAP effect on punching force

Lead researcher: Dr Andy Galbraith

Researcher: Mr Lee Brown

Researcher: Mr Gary Doyle

Researcher: Dr Alireza Monajati

Researcher: Mr Silvino Domingos

Your application to Ethics and Integrity Sub-Committee was considered on the 2nd of February 2022.

The decision is: **Approved**

The Committee's response is based on the protocol described in the application form and supporting documentation.

Your project has received ethical approval for 4 years from the approval date.

If you have any questions regarding this application please contact your supervisor or the secretary for the Ethics and Integrity Sub-Committee.

Approval has been given for the submitted application only and the research must be conducted accordingly.

Should you wish to make any changes in connection with this research project you must complete An application for approval of an amendment to an existing application.

The approval of the proposed research applies to the following research site.

Research site: UEL Docklands Campus

Principal Investigator / Local Collaborator: Dr Andy Galbraith

Approval is given on the understanding that the UEL Code of Practice for Research and the Code of Practice for Research Ethics is adhered to.

Any adverse events or reactions that occur in connection with this research project should be reported using the University's form for Reporting an Adverse/Serious Adverse Event/Reaction.

The University will periodically audit a random sample of approved applications for ethical approval, to ensure that the research projects are conducted in compliance with the consent given by the Research Ethics Committee and to the highest standards of rigour and integrity.

Please note, it is your responsibility to retain this letter for your records.

With the Committee's best wishes for the success of the project

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Appendices

Appendix A

Title

Appendix 2
Research integrity module certification

CERTIFICATE of ACHIEVEMENT

This is to certify that

Silvino DOMINGOS

has completed successfully

Research Integrity Modules

18 December 2019

End of course quiz - Natural and Physical Sciences Grade: 75.00 %

Appendix 3
Risk assessment form

Risk Assessment Form

Assessment no:

School of Health, Sport and Bioscience
University of East London

Brief outline of work/activity	To Understand the effect of PAP through the use of trunk rotational resistance training exercises on Punch performance	**Assessor:**	Gary Doyle
Location	Sports science laboratory at University of East London Fight for Peace Boxing Academy	**Signed off by Head of School or H&S coordinator**	

Hazards identified	Who might be at risk	Existing controls	Likelihood H M L	Severity H M L	Residual risk 1-9	Additional control measures required	Date actioned	Estimated residual risk
musculoskeletal injury	Participants	Screening, warmup, familiarisation, instruction and supervision	L	L	1			
Fall/slips	Participants/Staff	Endure floor is clear, no liquid or wires near participants	L	L	1			
Manual handling	Staff	Ensure correct lifting of equipment, if possible ask for assistance	L	M	2			
Personal Safety	Staff	Ensure to notify someone of whereabout and time of return	L	M	1			
Electrical Safety	Staff/participants	Tape down wires to the floor to minimise slipping. Ensure all equipment have been PAT tested and are safe to use.	L	M	1			

Appendix 4

UEL Data Management Plan: Full

Completed plans <u>must</u> be sent to researchdata@uel.ac.uk for review

If you are bidding for funding from an external body, complete the Data Management Plan required by the funder (if specified).

Research data is defined as information or material captured or created during the course of research, and which underpins, tests, or validates the content of the final research output. The nature of it can vary greatly according to discipline. It is often empirical or statistical, but also includes material such as drafts, prototypes, and multimedia objects that underpin creative or 'non-traditional' outputs. Research data is often digital, but includes a wide range of paper-based and other physical objects.

Administrative Data	
PI/Researcher	Silvino Domingos
PI/Researcher ID (e.g. ORCiD)	U1536083

)

PI/Researcher email	u1536083@uel.ac.uk
Research Title	Post-activation potentiation: The effect of a full body trunk rotational movement in punch mechanics.
Project ID	
Research Duration	One year, commencing September 2019
Research Description	Participants will be fitted with a linear position transducer to determine the velocity of a punch. Punches will be directed at the Powerkube portable accelerometers device positioned on a wall to determine punch kinetics during pre and post intervention. Participants will also be positioned standing on a force plate in order to determine rate of force development at an interval of 50ms. Upon resting after pre-test, participants will be randomly assigned to perform 5 repetition of a trunk rotational exercise in the form of a standing cable wood chop in two different resistance across two separate days. A five minute rest period will be given prior to commencing each post-test. Participants will wear hand wraps and boxing gloves during each test in order to protect the hands and limit the risk of injury. The condition will be performed in no less than a week apart. The purpose is to examine the effect of trunk rotational exercise during post activation potentiation in punch performance, and to compare the results across two different intensity.
Funder	Student Loan
Grant Reference Number (Post-award)	N/A
Date of first version (of DMP)	
Date of last update (of DMP)	
Related Policies	N/A

Does this research follow on from previous research? If so, provide details	N/A
Data Collection	
What data will you collect or create?	• A series of anthropometric data; height, body mass, age. • Biomechanical data including; punch velocity, punch impact force, rate of force development • Data will be analysed using Excel spreadsheets and SPSS software. • No personal data that could identify an individual will be collected, only consent and pre-test fitness questionnaire which include names, contact email, number, boxing training history, resistance training history, medical history and physical readiness to participant in exercise.
How will the data be collected or created?	• Measurements will be taken using scales and tape measure. • Biomechanical data will be collected using the linear position transducer, Powerkube and force plate • Data will be saved in an Excel file. • The force plate is used to collect the data which is retrieved as an Excel file. • Data will be inputted into Excel files, and stored in OneDrive with a copy on my personal UEL student H drive.
Documentation and Metadata	
What documentation and metadata will accompany the data?	
Ethics and Intellectual Property	
How will you manage any ethical issues?	Participants will be given an information sheet and asked to sign a consent form and complete a medical form before starting (see attached). The consent form will request consent from participants to publish and archive anonymised results of the research, as described in the 'data sharing' section of the data management plan. It is not anticipated that there will be any ethical issues beyond this. The data will be anonymised at source, personal information is limited to anthropometric data; height, body

	mass, training age, age. Data will be anonymised using codes such as P1 (Participant 1) which will be linked to all consent forms and medical forms.
How will you manage copyright and Intellectual Property Rights issues?	The ownership of the data is with the researcher, no third parties will be involved.
Storage and Backup	
How will the data be stored and backed up during the research?	Data will be transferred from the equipment via an encrypted USB stick to a OneDrive folder, with a back up on H drive at UEL. Medical and consent forms will be scanned and stored in H drive at UEL. Hard copies will be kept in a locked filing cabinet in a locked office in Docklands, until the end of the study and then shredded. Personal identifying data will be stored in a separate password protected, encrypted folder on H drive at UEL. Other non-identifying data will be stored in a OneDrive folder.
How will you manage access and security?	Both the OneDrive and H drive folders are password protected and only the researcher has access to them. Only the researcher will have the key to the locked filing Cabinet where the video cameras will also be stored. Raw video data will be maintained on the University's server (H: Drive) and participants will not be identifiable as all video data was taken from the hips downwards, not encrypted but will be password protected. The researcher, supervisory team and if requested the participant will be able to access their own data. Participants requiring access to their data will need to visit campus with a personal USB stick, so that their individual data can be transferred to them. This will avoid participants individual data being sent to them via email.
Data Sharing	
How will you share the data?	The final data analysis will be presented as part of the master's thesis and, where appropriate, as part of a peer reviewed journal. A fuller appraisal of data which could be shared will take place later in research: if selected, this will be shared after completion of the research, potentially under embargo to

	exploit publication opportunities. Anonymised data will be deposited in, and shared via UEL's repository.
Are any restrictions on data sharing required?	To be continued.
Selection and Preservation	
Which data are of long-term value and should be retained, shared, and/or preserved?	Raw data is potentially of long-term value as there is a lot of biomechanical information there which could be analysed at a later date, the same for the metabolic data.
What is the long-term preservation plan for the data?	Data suitable for preserving will be securely stored in the digital archive services provided by the library at UEL, with a retention period of 5 years, then reviewed every 5 years until transferred or destroyed. Digital copies of consent forms will be kept for the same period, hard copies will be kept in a locked cabinet until the completion of the testing period (one year), then destroyed. Additionally, raw video data will also be deleted after 12 months.
Responsibilities and Resources	
Who will be responsible for data management?	The researcher, Silvino DOmingos.
What resources will you require to deliver your plan?	A USB stick (researcher's own), access to the internet (OneDrive) and the H drive at UEL, lockable filing cabinet in SD2.09 and support from the Library and Learning Services to implement preservation plan.

Review	
	To be updated with further information regarding data sharing as indicated **Please send your plan to researchdata@uel.ac.uk** **We will review within 5 working days and request further information or amendments as required before signing**
Date: 2	Reviewer name:

Guidance

Brief information to help answer each section is below. Aim to be specific and concise.

For assistance in writing your data management plan, or with research data management more generally, please contact: **researchdata@uel.ac.uk**

Administrative Data

Related Policies

List any other relevant funder, institutional, departmental or group policies on data management, data sharing and data security. Some of the information you give in the remainder of the DMP will be determined by the content of other policies. If so, point/link to them here.

Data collection

Describe the data aspects of your research, how you will capture/generate them, the file formats you are using and why. Mention your reasons for choosing particular data standards and approaches. Note the likely volume of data to be created.

Documentation and Metadata

What metadata will be created to describe the data? Consider what other documentation is needed to enable reuse. This may include information on the methodology used to collect the data, analytical and procedural information, definitions of variables, the format and file type of the data and software used to collect and/or process the data. How will this be captured and recorded?

Ethics and Intellectual Property

Detail any ethical and privacy issues, including the consent of participants. Explain the copyright/IPR and whether there are any data licensing issues – either for data you are reusing, or your data which you will make available to others.

Storage and Backup

Give a rough idea of data volume. Say where and on what media you will store data, and how they will be backed-up. Mention security measures to protect data which are sensitive or valuable. Who will have access to the data during the project and how will this be controlled?

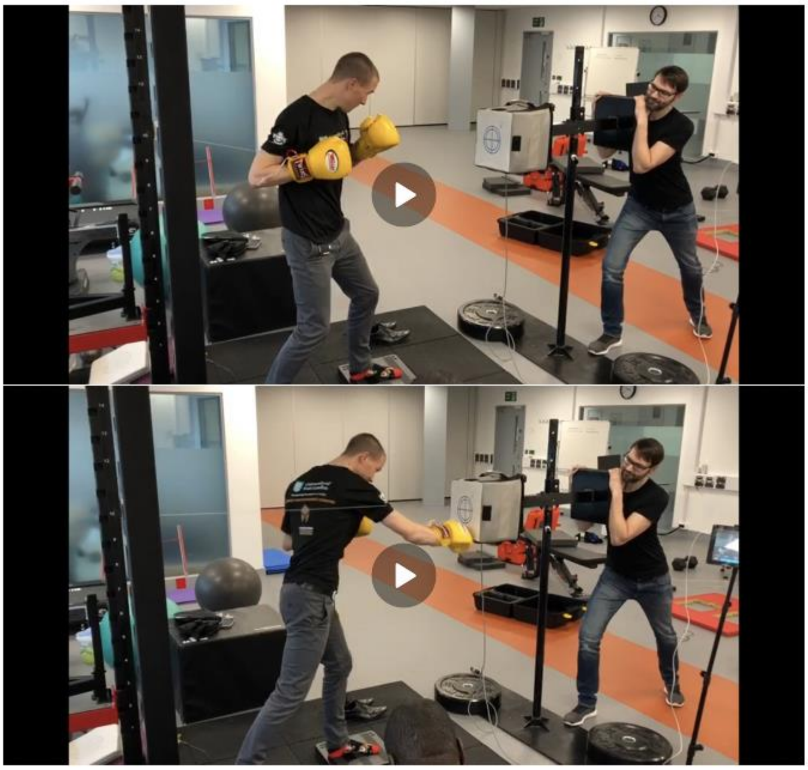
Data Sharing

Note who would be interested in your data, and describe how you will make them available (with any restrictions). Detail any reasons not to share, as well as embargo periods or if you want time to exploit your data for publishing.

Selection and Preservation

Consider what data are worth selecting for long-term access and preservation. Say where you intend to deposit the data, such as in UEL's data repository (data.uel.ac.uk) or a subject repository. How long should data be retained?

Appendix 5
Gym area



```
RELIABILITY
  /VARIABLES=Trial_1 Trial_2 Trial_3 Trial_4 Trial_5 Trial_6
Trial_7 Trial_8 T rial_9 Trial_10
  /SCALE('2kg Medicine Ball dropped at 4 different height') ALL
  /MODEL=ALPHA
  /SUMMARY=MEANS
  /ICC=MODEL(RANDOM) TYPE(ABSOLUTE) CIN=95 TESTVAL=0.
```

Reliability

Notes

Output Created		30-OCT-2019 14:55:...
Comments		
Input	Data	/Users/silvinodomingos/Desktop/Sports and Exercise Science/Years/4th Year - Masters/Research Study/Data/Spss Reliability data.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	4
	Matrix Input	
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=Trial_1 Trial_2 Trial_3 Trial_4 Trial_5 Trial_6 Trial_7 Trial_8 Trial_9 Trial_10 /SCALE('2kg Medicine Ball dropped at 4 different height') ALL /MODEL=ALPHA /SUMMARY=MEANS /ICC=MODEL (RANDOM) TYPE (ABSOLUTE) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: 2kg Medicine Ball dropped at 4 different height

Case Processing Summary

		N	%
Cases	Valid	4	100.0
	Excluded[a]	0	.0
	Total	4	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.998	.999	10

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance
Item Means	1495.975	1369.000	1557.500	188.500	1.138	4387.076

Summary Item Statistics

	N of Items
Item Means	10

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0		
		Lower Bound	Upper Bound	Value	df1	df2
Single Measures	.982[a]	.940	.999	548.442	3	27
Average Measures	.998	.994	1.000	548.442	3	27

Intraclass Correlation Coefficient

	F Test with
	Sig
Single Measures	.000

.

```
/SCALE('3kg Medicine Ball dropped at 4
different height') ALL
/MODEL=ALPHA
/SUMMARY=MEANS
```

Reliability

Notes

Output Created		30-OCT-2019 14:55:...
Comments		
Input	Data	/Users/silvinodomingos/Desktop/Sports and Exercise Science/Years/4th Year - Masters/Research Study/Data/Spss Reliability data.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	4
	Matrix Input	
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=Trial_1 Trial_2 Trial_3 Trial_4 Trial_5 Trial_6 Trial_7 Trial_8 Trial_9 Trial_10 /SCALE('3kg Medicine Ball dropped at 4 different height') ALL /MODEL=ALPHA /SUMMARY=MEANS /ICC=MODEL (RANDOM) TYPE (ABSOLUTE) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: 3kg Medicine Ball dropped at 4 different height

Case Processing Summary

		N	%
Cases	Valid	4	100.0
	Excluded[a]	0	.0
	Total	4	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.999	1.000	10

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance
Item Means	2655.050	2488.500	2802.750	314.250	1.126	10796.581

Summary Item Statistics

	N of Items
Item Means	10

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0		
		Lower Bound	Upper Bound	Value	df1	df2
Single Measures	.991[a]	.969	.999	1233.021	3	27
Average Measures	.999	.997	1.000	1233.021	3	27

Intraclass Correlation Coefficient

	F Test with
	Sig
Single Measures	.000

```
/SCALE('5kg Medicine Ball dropped at 4
different height') ALL
/MODEL=ALPHA
/SUMMARY=MEANS
```

Reliability

Notes

Output Created		30-OCT-2019 14:56:...
Comments		
Input	Data	/Users/silvinodomingos/Desktop/Sports and Exercise Science/Years/4th Year - Masters/Research Study/Data/Spss Reliability data.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	4
	Matrix Input	
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=Trial_1 Trial_2 Trial_3 Trial_4 Trial_5 Trial_6 Trial_7 Trial_8 Trial_9 Trial_10 /SCALE('5kg Medicine Ball dropped at 4 different height') ALL /MODEL=ALPHA /SUMMARY=MEANS /ICC=MODEL (RANDOM) TYPE (ABSOLUTE) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: 5kg Medicine Ball dropped at 4 different height

Case Processing Summary

		N	%
Cases	Valid	4	100.0
	Excluded[a]	0	.0
	Total	4	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.999	.999	10

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance
Item Means	4891.700	4419.500	5134.500	715.000	1.162	34377.219

Summary Item Statistics

	N of Items
Item Means	10

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0		
		Lower Bound	Upper Bound	Value	df1	df2
Single Measures	.988[a]	.958	.999	770.707	3	27
Average Measures	.999	.996	1.000	770.707	3	27

Intraclass Correlation Coefficient

	F Test with
	Sig
Single Measures	.000

```
/SCALE('ALL VARIABLES') ALL
/MODEL=ALPHA
/SUMMARY=MEANS
```

Reliability

Notes

Output Created		**30-OCT-2019 14:57:...**
Comments		
Input	**Data**	**/Users/silvinodomingos/Desktop/Sports and Exercise Science/Years/4th Year - Masters/Research Study/Data/Spss Reliability data.sav**
	Active Dataset	**DataSet1**
	Filter	**<none>**
	Weight	**<none>**
	Split File	**<none>**
	N of Rows in Working Data File	**12**
Missing Value Handling	**Matrix Input**	
	Definition of Missing	**User-defined missing values are treated as missing.**
	Cases Used	**Statistics are based on all cases with valid data for all variables in the procedure.**
Syntax		**RELIABILITY /VARIABLES=Trial_1 Trial_2 Trial_3 Trial_4 Trial_5 Trial_6 Trial_7 Trial_8 Trial_9 Trial_10 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /SUMMARY=MEANS /ICC=MODEL (RANDOM) TYPE (ABSOLUTE) CIN=95 TESTVAL=0.**
Resources	**Processor Time**	**00:00:00.00**
	Elapsed Time	**00:00:00.00**

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	**Valid**	12	100.0
	Excluded[a]	0	.0
	Total	12	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items

.999	.999	10

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance
Item Means	3014.242	2881.500	3069.167	187.667	1.065	4463.754

Summary Item Statistics

	N of Items
Item Means	10

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0		
		Lower Bound	Upper Bound	Value	df1	df2
Single Measures	.990[a]	.979	.997	965.126	11	99
Average Measures	.999	.998	1.000	965.126	11	99

Intraclass Correlation Coefficient

	F Test with
	Sig
Single Measures	.000
Average Measures	.000

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

Appendix 6

BASES Pre-test Questionnaire

Name……………………………………………………………………………………
Date of Birth…………………………….
Age……………………………………….

As you are to be a client in this assessment, would you please complete the following questionnaire. Your co-operation in this greatly appreciated

* = Please circle to indicate response

ANY INFORMATION CONTAINED HEREIN WILL BE TREATED AS CONFIDENTIAL

1. How would you describe your present level of activity?

Sedentary/moderately active/ highly active*
Give an example of typical weeks exercise.

2. How would you describe your present level of fitness?

Very unfit/moderately fit/trained/highly trained*

3. How would you consider your present body weight?

Under weight/ideal weight/slightly overweight/very overweight*

4. Smoking Habits:

Currently non-smoker	yes/no*
A previous smoker	yes/no* of…..per day
If *previous smoker*, how long since stopping?……….years	
Regular smoker	yes/no* of…..per day?
An occasional smoker	yes/no* of…..per day?

5. Consumption of alcohol:

Do you drink alcoholic drinks? yes/no*

If *yes*, then do you:

Have the occasional drink?	yes/no*
Have a drink every day?	yes/no*
Have more than one drink a day?	yes/no*

Please indicate the type of alcoholic beverage you consume i.e. beer, spirits, shandy

6. Have you had to consult your doctor within the last 6 months? yes/no*
If *yes*, please give relevant details to the test supervisor.

7. Are you presently taking any form of medication? yes/no*
If *yes*, please give relevant details to the test supervisor.

8. Do you suffer, or have you ever suffered, from

Asthma? yes/no*
Diabetes? yes/no*
Bronchitis? yes/no*
Epilepsy? yes/no*

9. Do you suffer, or have you ever suffered from, any form of heart complaint? yes/no*

10. Is there a history of heart disease in your family? yes/no*

11. Do you currently have any form of muscle or joint injury? yes/no*

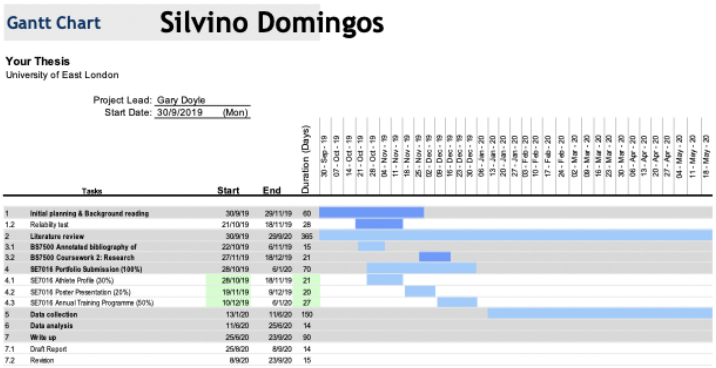
12. Have you had any cause to suspend your normal training in the last two weeks? yes/no*

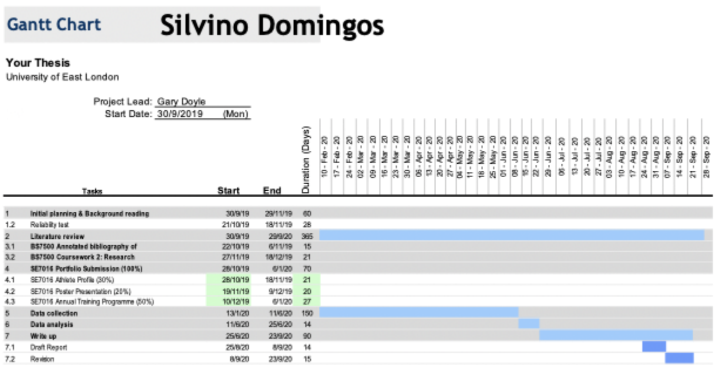
13. Is there anything to your knowledge that prevent you from successfully completing the tests that have been outlined to you? yes/no*

Signature of client……………………………………. Date……………………

Signature of test supervisor……………………………..

Appendix 7
Gantt Chart





Appendix 9
Force plate

Appendix 10
linear position transducer

Appendix 11

Powerkube