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# A Four Week Contrast Training Programme Enhances Punch Performance and Physical Qualities in Senior Elite Amateur Boxers: A Physical Preparation Case Study for an International Tournament

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## ABSTRACT

This case study aimed to design a 4-week training intervention and monitor the physical capabilities of three amateur boxers as they prepared for and competed in a distinguished international boxing tournament. Three male senior elite amateur boxers (19.3 ± 1.5 years; height 178 ± 3 cm; mass 77 ± 4.6 kg) visited the laboratory on three separate occasions across an 8-week period around competition. Specifically, participants performed baseline physical tests comprising one repetition maximum of bench press and hex bar deadlift, counter-movement jumps, maximal punches against a vertically mounted force plate, and the Yo-Yo Level 1. This testing battery was repeated following a 4-week contrast training intervention prior to competition, and again following competition. Generally, meaningful or worthwhile improvements in all physical performance tests from baseline to pre-competition was observed. An increase of between 1.4% to 8.1% in punch force was also observed. Likewise, improvements in jump height of between 0.1% and 3.1% were found. Performance gains were maintained at post-competition, albeit with a downward trend towards baseline values. In conclusion, the 4-week contrast training intervention implemented by amateur boxers preparing for competition, served to improve general physical performance qualities, and perhaps more importantly, punch force. In a time-limited scenario, a 4-week contrast training programme may be an effective method of improving punch-specific and physical performance, thus perhaps transferring to greater performance in the ring. Future research may wish to explore the effectiveness of longer-term training methods.

Keywords: Boxing; contrast training; competition; kinetics; performance

## INTRODUCTION

Amateur boxing is a multi-directional and intermittent combat sport, with the male format typically competed across 3-x-3-minute or 3-x-2 minute rounds, interspersed by 1-minute active and passive recovery[1,2]. As the only method of attack, a forceful and effective punch is of great importance, be it to knockout an opponent, or to inflict an accumulation of damage on the way to a points victory. Notational analysis from elite competition in the UK and Australia, suggest boxers throw between 61 – 78 punches in a round[1,2]. Further, some of the above studies show that boxers land between 13-29% of the punches thrown, with greater punch accuracy rather than frequency, associated with bout success. Likewise, ~10 combinations are performed during a round, with a combination defined as a cluster of 2 or more punches. Data on defensive actions in the literature varies, perhaps due to differences in movement classifications and methods of notation. Nevertheless, elite Australian amateur boxers perform ~30 defensive actions in a round[2]. This activity profile of amateur boxing, mixed with the short recovery periods in-between rounds, suggests the sport is predominantly aerobic in nature, with anaerobic contributions[3,4], and induces a considerable physiological, endocrine, and biochemical demand on boxers[3,4,5].

In the current case study, the head coach of the amateur boxers wanted to improve their punch force and general athletic capabilities, in preparation for one of the most prestigious and largest amateur boxing tournaments in Europe, the Haringey BOX cup, in 5 weeks' time. To produce effective punches, and be able to sustain a similar workload discussed in the section above, boxers are required to have well-developed aerobic capacity and anaerobic power, speed, high levels of muscular strength, 'power', and endurance[5]. A review of literature on the physical qualities of male amateur boxers show a $VO_{2max}$ in the range of 49 and 65 ml/kg/min$^{-1}$, whilst performance in 30-second Wingate tests are routinely comparable to judo, karate, and taekwondo athletes[5]. Previous research suggests strength and 'power' levels in general physical tests correlate with peak punch force[6,7,8]; however, for practitioners aiming to develop punch force in boxers, a focus on maximal strength in the lower-body, and power in the upper-body, may be seen as a worthwhile strategy[6,7]. Punch force in amateur boxing when considering each punch type, is ~ 2500 N[7,8,9,10], though the differences in study methodologies show a large variation in punch force in the literature. Peak punch force is typically greater in the cross (range 1331 to 4800 N) and hook punches (range 2412 to 2622 N). The latter may be under-reported in the scientific literature, due to difficulties in quantifying hook punches in some studies. Boxers are required to produce this force rapidly (rate of force development), to evade an opponent's defensive manoeuvres.

The cross punch comprises a kinetic sequence starting with the production of ground reaction forces, rear leg drive and transfer of bodyweight from rear foot to front foot, rotation at the pelvis and trunk and the propulsion of the upper extremities at high velocities prior to impact[9,11-13]. The hook technique shares some similarities with the cross, in that it also comprises considerable peak lead leg GRF, rotation at the trunk, and high velocities of the most distal point at impact. The hook technique represents an SSC component, whereby a pre-stretch of trunk and upper body musculature is performed prior to propelling the upper extremities towards the target[9,11-13]. This includes the 'loading' of the lead leg, whereby greater peak GRF may be evident in the lead leg, compared to the rear leg. As such, and admittedly at the risk of simplifying complex processes, any physical training programme should include activities aimed at yielding greater force production at the lower limbs, twisting motion at the trunk, and high distal-point velocities[14]. In briefly reviewing the typical physical qualities of amateur boxers and the biomechanics of punching technique, we can ascertain which physical qualities may be pertinent to performance, and tailor a strength and conditioning programme that may serve to achieve desirable adaptations.

The benefits of strength training to general physical qualities such as strength and power, and to injury reduction, is well established[15,16]. As already mentioned, research has shown the relationship between strength and power levels, and punch impact force in elite amateur boxes[6,7,8]. However, only a select few studies have explored the use of resistance training interventions to improve punch characteristics in boxers[17-19], potentially due to the difficulty in quantifying variables related to punch performance, or perhaps the challenges in controlling confounding variables from a high training load, or rapid weight making practices. In an unpublished but pertinent piece of research, Stanely[19] showed a 4-week training programme of contrast training improved punch force by ~10% when compared to a maximal strength training intervention of the same duration. Likewise, Del Vecchio and colleagues[17] found moderate improvements in kicking and rear hand punch impact power following general strength and power training, compared to a control trial of combat-related training. Loturco and colleagues[18] reported an ~8% increase in punch impact force following a strength and power training programme at the optimal power load, of just one week duration. These studies have shown the potential benefits of strength and power related training on punch-specific and neuromuscular performance, including during time-limited training phases, though this unfortunately represents a small body of research.

The aim of the case study was to monitor individual punch force and physical performance of amateur boxers, following a 4-week strength and conditioning intervention in preparation for competition. To do this, a review of the head coach requirements, a consultation of the scientific literature on amateur boxing, and a reflection of the time-limited context and logistical barriers of the athletes competition schedule, would be considered.

## METHODS

### *Subjects*

Three male senior elite amateur boxers (19.3 ± 1.5 years; height 178 ± 3 cm; mass 77 ± 4.6 kg) took part in the study. The study was conducted during the amateur boxing season, and was centred around an international boxing tournament, the Haringey BOX Cup. As part of a related research project[20], boxers were familiar with all elements of the physical testing battery, had completed a comprehensive health screening procedure, and were informed of the benefits and risks of the project by the lead researcher, and the head coach. The study was conducted in accordance with the Helsinki Declaration.

### *Design*

A case study design was utilised to explore the effectiveness of a short block of contrast training on the physical and punch-specific performance of amateur boxers, competing at an international tournament.

### *Methodology*

#### *Physical Fitness Testing*

Following an assessment of the determinants of performance, both from the scientific literature described earlier, and from discussions with the head coach, a battery of fitness tests were established. Initially, boxers completed the baseline physical testing session, inclusive of the tests in the following section. All tests included in the testing battery were repeated a further two times, in the week prior to the competition, and within a two-week period following the competition. Details of the tests can be seen below.

#### *Maximal Punch Force*

The athletes performed 3 repetitions of the following punch types; cross, lead hook, and rear hook, against a vertically mounted force plate (Bertec, Columbus, USA). Each punch was interspersed by 5s recovery. The force plate sampling at 2000 Hz was vertically mounted to a custom-built steel apparatus and comprised custom high-density foam padding (72 x 42 x 10cm) enclosed in a rectangular case. The height of the force plate was manipulated according to each participants height. Force data was captured using a motion capture system (Qualysis, Inc. Sweden). Specifically, force signals were transferred to a AM6500 digital signal converter. Data were exported to a large Microsoft Excel datasheet, whereby peak and mean impact forces for each punch type were analysed. Previous research has shown the vertically mounted force plate demonstrated excellent within-session (ICC 0.96 - 0.99) and good to excellent between-session (0.89 – 0.98) reliability for absolute peak impact force[9]. For all punching trials, the athletes were advised to apply protective hand wraps in their typical manner. The athletes were advised to strike a diamond target of case surrounding the force plate and were asked to adopt their typical technique (e.g., self-selected distance) based on Loturco et al[8]. This increased the ecological validity of the test.

#### *Countermovement Jump (CMJ)*

The athletes performed 3 maximal effort CMJ's (no arm-swing) interspersed by 10-seconds rest, monitored via a photocell system (Optojump, Microgate, Bolzano, Italy). This method has shown adequate reliability ICC 0.98 (0.95 – 0.99) when assessing lower body neuromuscular performance in amateur boxers[21]. Peak and mean jump height (cm) at each testing interval was obtained.

#### *One Repetition Maximum (1RM) Strength Assessments*

The boxers upper and lower body maximal strength was assessed via 1RM tests in the bench press and trap bar deadlift, with the former inspired by a previous protocol[22]. The protocols comprised standardised incremental increases in load, followed by a standardised rest, with the athletes 1RM being the final load successfully lifted.

*Yo-Yo Intermittent Recovery Test – Level 1 (YYIRL1)*

The athletes performed level one of the Yo-Yo intermittent recovery test (YYIRL1) as a field-based assessment of aerobic capacity. This test is commonly applied in team sports; however, due to it's intermittent nature and perhaps more importantly it's practicality, it may also be appropriate for use in amateur boxing[21]. A recent review reported that this test generally had good-to-excellent relative reliability (ICC's ≥ 0.90) and low CV% of <10%[23].

The participants attended the laboratory three times for this specific project. As mentioned above, boxers also attended several other testing sessions as part of related research projects, and so were fully accustomed to the testing procedures of the current case study.

*Standard testing procedures*

It is worth noting the pre-testing controls implemented in the case study. The athletes were asked to refrain from vigorous exercise, and consumption of alcohol or stimulants for a 48-h prior to each assessment[24]. Anthropometric data (height and body mass) were collected at the start of each assessment. Following this, in all assessments, with the exception of the 1RM strength assessments, participants initially performed a standardised RAMP warm-up, inclusive of 'task-specific' activity that they were familiar with, this can be seen in table 1.

The 1RM assessments were preceded by a standardised warm-up of 2 x 8 banded shoulder rotations, 2 x 8 banded face pulls, 2 x 5 Push-ups, and 2 x 5 sub-optimal repetitions of the main lift.

*Contrast training programme*

Due to the short time from the head coach request, and the start of the competition, there would only be 5-weeks to implement a training intervention. However, this would essentially be 4-weeks, due to the need for initial baseline assessments. This is notably shorter compared to a typical 10-to-12-week camp seen in the professional format[14], whereby a block structure or other approach could be implemented, with the affordance of appropriate general preparation and a taper. This short period in amateur boxing is not uncommon, owing to more demanding bout schedules. One method that is used in the scientific literature, and indeed in the field to improve strength and power qualities of

**Table 1.** RAMP warm-up used prior to maximal punching and CMJ assessments.

| R-A-M-P | Intensity | Examples | Time | Why |
|---|---|---|---|---|
| Raise | Light-to-moderate pulse raising activity | • Shadow box<br>• Skipping | ~5-mins | Stimulate blood flow<br><br>Increase muscle temperature<br><br>Increase oxygen delivery and uptake<br><br>Task-specific activity |
| Activate and Mobilise | Light-to-moderate intensity dynamic activation and mobility | • BW squats<br>• BW walking lunges<br>• Banded scap pulls<br>• Banded hand openings<br>• Mini-band activity<br>• Balance activity<br>• Shoulder wall slides<br>• Spiderman lunge<br>• Supermans<br>• Eagles | ~5-mins | Acutely enhance ROM and mobilise key joints used in boxing<br><br>Activate key muscle groups used in boxing and enhance free-coordinated movement |
| Potentiate/ Performance | High-intensity task-specific activity | • Pad work and lower-body plyometrics | ~5-mins | Progress intensity towards that of competition<br><br>Task-specific element, potential to induce PAPE |

*CA = Conditioning activity; PAPE = Post Activation Performance Enhancement; ROM = Range of motion.*

**Table 2.** General structure of the athlete's programme in the lead up to, and post-competition.

| General structure of activity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Week** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| Activity | Familiarisation | Boxing-specific training | | | | Competition | Post-competition | |
| | Baseline assessments | Contrast training intervention | | | | | Post-competition assessments | |
| | | | | | Post-intervention assessments | | | |

athletes in a short time period, is contrast training. Cormier and colleagues[25] define contrast training as "combination training that involves the use of contrasting heavy and light loads", adding that the heavy loaded exercise is typically performed prior to the low load, or plyometric/ballistic activity. This method has been used extensively in team sports and has also been applied to a boxing cohort[19]. In the work by Stanley[19], punch force was not measured by a vertically mounted force plate, but a Herman Digital Trainer, thus only minimal information on the accuracy, validity, and reliability of the instrument is available. Whilst this means we should interpret the results with caution, it also suggest further exploration of the potential benefits of contrast training to this cohort, should be conducted. Interestingly, Stanley also reported greater gains in back squat and bench press strength following the contrast training protocol, compared to the maximal strength programme[19]. The author notes that this may have been due to the inclusion of 'high-force' exercises in addition to high-velocity movements. The combination of both may enhance 'explosive' performance, perhaps due to the post-activation performance enhancement (PAPE) phenomenon[20,26]. Therefore, a 4-week contrast training intervention, aimed at increasing general strength and power qualities, with the inclusion of punch-specific exercises aimed at improving punch force, was chosen. Table 2 shows the general structure of the athlete's programme.

Due to the continuation of boxing-specific training throughout the 4-week intervention, strength and power-based training was to be implemented only two times per week. This has been shown to be sufficiently effective in inducing improvements in strength, in trained individuals[27]. Only a single session of conditioning, based on high-intensity interval training (HIIT) was chosen to minimise fatigue, whilst the athletes were also partaking in their boxing-specific conditioning via sparring, and a 3x800m running session at the behest of the head coach. Table 3 highlights the activity performed in the contrast training sessions (Tuesday and Thursday).

**Table 3.** Details of the activity performed during the 4-week intervention.

| **Day** | **Activity - (All resistance-based activity was 3 sets of 5 repetitions (3x5)** |
|---|---|
| Monday | Boxing technical training<br>3x800m |
| Tuesday<br>3 x 5 | Box jumps and altitude landing<br>MB rugby pass<br><br>Hex bar deadlift<br>Hex bar jumps<br>DB Press (banded)<br>MB supine chest pass<br>TRX row ISO hold<br>Pendlay row<br><br>Choice of accessory activity |
| Wednesday | Boxing technical training |
| Thursday<br>3 x 5 | Single broad jumps<br>Skater<br><br>ISO punch hold<br>MB 'punch-specific'<br>Back squats<br>CMJ<br>Weighted push-ups<br>PLYO push-ups<br>RDL<br><br>Choice of accessory activity |
| Friday | Sparring and/OR boxing technical training |
| Saturday | HIIT* |
| Sunday | No training |

The specific exercises and sets and repetition schemes were based on the broader scientific literature and literature pertaining specifically to combat sport[19,20,25], whilst simplicity of this brief programme, and the anecdotal experience of the author in their role as a strength and conditioning coach and applied sport scientist in combat sport, were also considered. Exercises included compound lifts aimed at increasing maximal strength and inducing a PAPE effect in the subsequent low load, or plyometric/ballistic exercise performed just minutes after[19,20,26,28]. Where possible, each pairing of exercises comprised biomechanical similarities[20], such as the same muscle groups used, and/or similar joint angles and direction of applied force. The main difference within the pairings, is of course the greater movement velocities in the second exercise, compared to the first.

### *Statistical Analyses*

Changes in punch force and CMJ performance across the three time points were assessed against previously determined smallest worthwhile change (SWC) thresholds[9]. More specifically, individual SWC thresholds were obtained from an individual coefficient of variation (CV) derived from repeated tests for each variable, calculated as follows: 0.3 × within-subject CV, expressed as a percentage[29]. As such, mean change and the % change in performance from baseline assessments was directly compared to the individual SWC. The calculation of the SWC was not undertaken for the strength assessments or the YYIR1, as this may have required additional assessments to obtain the individual coefficient of variation (CV) across repeat testing. Nevertheless, any changes in performance were recorded, and presented as mean and % change. Effect sizes (Cohens *d*) were calculated by dividing the mean difference between baseline and each time interval, by the pooled SD, with the following thresholds applied; small (0.2), medium (0.5) and large (0.8) effects. The above analysis was performed on a custom-made spreadsheet created by the author. All data are reported as mean ± SD, percentage, or ES, unless otherwise stated.

## RESULTS

Changes in punch force and jump height data over the three time periods can be seen in table 4.

## DISCUSSION

This case study aimed to assess the changes in punch-specific and physical performance of senior elite amateur boxers, following a 4-week contrast training programme. Though results across tests, and indeed across athletes varied, there was typically an improvement in punch-specific and physical performance from baseline, to pre-competition. This increase in performance was also evident from baseline to post-competition, albeit the differences were typically smaller in comparison.

**Table 4.** Punch-specific and physical performance data for each individual athlete at baseline, at pre-competition vs baseline, and at post-competition vs baseline.

| Athlete | Variable | SWC% (0.3xCV) | Baseline assessment | Pre-competition Δ from baseline | Post-competition Δ from baseline |
|---|---|---|---|---|---|
| A | Cross (N) | 0.9 | 2603 ± 74 | 2736 ± 61; 5.1% | 2694 ± 59; 3.5% |
| | L Hook (N) | 0.7 | 2518 ± 59 | 2626 ± 64; 4.3% | 2629 ± 54; 4.4% |
| | R Hook (N) | 0.8 | 2731 ± 69 | 2860 ± 57; 5.1% | 2805 ± 63; 2.7% |
| | CMJ height (cm) | 0.4 | 41.3 ± 0.7 | 42 ± 0.6; 1.7% | 41.8; 1.1% |
| | Bench press (kg) | | 102.5 | 112.5; 9.8% | 112.5; 9.8% |
| | Hex Deadlift (kg) | | 136 | 141; 3.7% | 143.5; 5.5% |
| | YYIRL1 Distance (m) | | 1464 | 1534; 4.8% | 1504; 2.7% |
| B | Cross (N) | 1.0 | 2129 ± 68 | 2234 ± 72; 4.9% | 2209 ± 70; 3.8% |
| | L Hook (N) | 1.2 | 2261 ± 91 | 2398 ± 76; 6.1% | 2353 ± 57; 4.1% |
| | R Hook (N) | 1.1 | 2441 ± 88 | 2639 ± 63; 8.1% | 2570 ± 51 ; 5.3% |
| | CMJ height (cm) | 0.2 | 39.2 ± 0.3 | 40.4 ± 0.5; 3.1% | 40.2 ± 0.3; 2.6% |
| | Bench press (kg) | | 77.5 | 82.5; 6.5% | 82.5; 6.5% |
| | Hex Deadlift (kg) | | 116 | 126; 8.6% | 131; 12.9% |
| | YYIRL1 Distance (m) | | 1620 | 1675; 3.4% | 1680; 3.7% |
| C | Cross (N) | 0.8 | 2540 ± 69 | 2534 ± 64; - 0.2% | 2576 ± 58; 1.4% |
| | L Hook (N) | 0.5 | 2603 ± 44 | 2638 ± 49; 1.3% | 2661 ± 49; 2.2% |
| | R Hook (N) | 0.5 | 2697 ± 49 | 2758 ± 51; 2.3% | 2760 ± 68; 2.3% |
| | CMJ height (cm) | 0.6 | 39.3 ± 0.8 | 39.4 ± 0.2; 0.1% | 39.6 ± 0.2; 0.8% |
| | Bench press (kg) | | 90 | 90; 0% | + 2.5; 2.8% |
| | Hex Deadlift (kg) | | 146 | 148.5; 1.7% | + 7.5; 5.1% |
| | YYIRL1 Distance (m) | | 1344 | 1384; 3.0% | + 55; 4.1% |

*Data are mean and SD, and percentage where possible. cm = Centimetres; CMJ = Countermovement jump; kg = Kilograms; m = Metres; N = Newtons; SWC = Smallest worthwhile change (0.3 x withing-subject coefficient of variation %); YYIRL1 = Yo-Yo Level 1 Intermittent Recovery Test*

### *Punch-specific*

Punch force exhibited by the boxers in the current study falls within the range seen in the literature[9,10,11]. An increase of between 1.4% to 8.1% in peak punch force was observed at pre-competition, when compared to baseline. This was similar to the punch performance improvements observed in a 4-week contrast training programme reported by Stanley[19]. Each athlete was deemed to have shown a 'worthwhile' change when considering the greatest individual SWC in this test was 1.2%. The data show that the contrast training programme aimed at developing strength and power, particularly lower-body strength, and upper-body power, was successful in inducing a punch-specific performance benefit. The reasons behind some of the observed changes in punch force may lie in the increased ability to produce GRF, a key component of a punch[11-13,] progressively targeted via lower-body strength exercises such as the hex bar deadlift and back squat. In longer-term training phases this could be progressed to unilateral, or staggered variations of said exercises. Likewise, unilateral lower and upper-body exercises aimed at increasing strength and distal point velocities (such as the banded DB press in relation to the latter) may have also influenced the changes in punch performance. Furthermore, the addition of plyometric and ballistic exercises which may contribute to an enhanced ability to utilise the stretch-shortening cycle, or in the case of transverse plane throws, may aid in the ability to rapidly rotate at the trunk[12-14], may partly explain some of the increase in punch force. In some cases, biomechanical specificity of the 'special' or 'punch-specific' exercises in relation to the sporting action itself (e.g., muscle groups used, joint angles, movement velocity) were included. As an example, the inclusion of an isometric punch hold was based on the apparent end range "stiffening" observed in a boxers punch[14]. Specifically, there is evidence of a double "peak" in muscle activity during striking techniques, whereby "stiffening" of the body at impact occurs, thus creating effective mass and reduced energy loss. All the above may have contributed somewhat to the increase in punch force.

Both Athlete A and Athlete B saw decreases of between 0.1 – 2.8% in punch force from pre-competition to post-competition. In all punches, this was still greater when compared with baseline values, suggesting the punch-specific performance enhancement emanating from the training intervention were still apparent. This may not be surprising when we consider the post-competition testing took place within two-weeks from competition, thus any detraining effects from training cessation, may not have occurred[30]. It is worth noting; however, the downward trend in most variables at the post-competition phase, compared to pre-competition. Interestingly, Athlete C maintained, and in some cases, improved punch-specific performance at post-competition, compared to pre-competition. Athlete C resumed training, albeit at light intensities, during the post-competition testing phase, as they were scheduled for another bout in a matter of weeks. This could partly explain why Athlete C did not follow the trend of punch force values returning closer to baseline values. Alternatively, this could be explained by Athlete C's initial punch force increases from baseline to pre-competition, being much smaller in magnitude compared to the other athletes.

### *Physical Performance*

Increases in jump height of between 0.1% and 3.1% were seen across all athletes, and across all time points. Again, the trend for performance to increase at pre-competition, then return closer to baseline at post-competition for Athlete A and B, but not Athlete C, was evident. The increases in jump height across the training intervention show that athletes were able to enhance their lower-body neuromuscular performance. We have already established the link between lower-body strength and punch force[6-8], but equally important is the inclusion of lower-body exercises aimed at improving the ability to produce force quickly.

Similar to punch-specific and CMJ performance changes, all athletes experienced improvements in 1RM of bench press and hex deadlift. This ranged between 2.8% and 9.8%. In contrast to the punch-specific data, in the majority of cases athletes not only improved their 1RM's from baseline to pre-competition, but also from pre-competition to post-competition. The reason for this is not known; however, it may partly be explained by a lack of accumulated fatigue from strength training, 1RM assessments, and repeat-bout competition in the prior weeks. The 4-week contrast programme was effective in producing modest strength gains in all athletes.

Lastly, improvements in IRL1 performance were also consistent across all athletes. This suggests the 4-week training intervention may have been effective in improving the aerobic fitness of the boxers in the study. However, as detailed in later sections, caution must be applied due to several confounding factors.

Generally, positive performance changes were observed in all variables, at almost each re-assessment, in almost all athletes. Importantly, meaningful changes > SWC were typically observed in punch force and CMJ performance at pre-competition. Thus, the intervention may have had a positive outcome. The author is keen to use the term 'may' have, as opposed to 'did have', as without a randomised control study, inclusive of a trial of no intervention, we cannot be certain that this was purely due to the intervention itself. Indeed, this is the first limitation of the case study to note, elaborated upon in the next section.

## LIMITATIONS

The first limitation may be the inability to assess whether traditional strength training induces similar or different performance outcomes, as the contrast training programme in the current study. However, this is a case study design. Further research may wish to explore this in a larger cohort. In the current study there were also many confouding variables, most notably the boxing-specific training and conditioning being performed by the athletes will undoubtedly have had an effect. For example, it is not certain whether the HIIT session included in the 4-week programme actually improved athlete conditioning, beyond the boxing-specific conditioning, and the head coaches 3x800m session. However, it is apparent that the overall training intervention and boxing-specific activity had, at the very least complimented each other, and resulted in meaningful changes in punch-specific and physical performance. Another limitation is the short duration of the intervention. Any magnitude of observed change would be constrained by the short time period of the intervention and the support. This of course influenced the decision to create a short-term contrast training programme. Therefore, it had been agreed by the head coach and the researcher that further scientific support with the athletes would, and did, ensue. Linked to the above point, there was only a short time period between the pre-competition and post-competition assessments. This may also have implications for rehydration, refuelling and any subsequent gains in body mass post-competition, though as previously stated, large fluctuations in body mass were not observed in this case study. Nevertheless, the lack of consistent monitoring of body mass fluctuations outside of the three testing time points, is perhaps a limitation of this case study. The author acknowledges the limitations in case study designs, but also the unique advantages of their real-world application.

## PRACTICAL APPLICATIONS

The contrast training intervention produced meaningful improvements in punch-specific and physical performance in amateur boxers preparing for an international tournament. Considering there is typically a short turnaround between bouts in amateur boxing, the exercises and programme structure observed in the present study could be used by boxing coaches to prepare for domestic and international tournaments.

## CONCLUSION AND FUTURE RECOMMENDATIONS

In conclusion, the 4-week training intervention in the present study improved punch-specific and physical performance of amateur boxers. Findings from this study may also be relevant to other combat sports with a striking element. Future research should apply a longer-term training intervention and monitor the punch-specific and physical performance changes throughout an amateur boxing season. Likewise, future research could explore the effects of resistance priming within the acute periods prior to, or between bouts.

## CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

## FUNDING

This study received no specific funding in order to be completed.

## ETHICAL APPROVAL

Ethics for this study were approved in line with University's ethics procedure.

## DATES OF REFERENCE

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