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Physiological profile of a professional boxer preparing for Title Bout: A case study

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ABSTRACT

This study aimed to (1) profile a professional boxer (23 years and 80 kg) with boxing-specific, muscle function, aerobic capacity and body composition tests, and (2) quantify how these measures varied during an 8-week preparation phase leading to, and post a state-Title Bout fought in the 76.2-kg class. A series of boxing-specific and muscle function tests were completed on 11 occasions: 9 prior and twice after the bout, each separated by approximately 2 weeks. The boxing test included 36 maximal punches (9 of each: lead and rear straights, lead and rear hooks) to a punching integrator measuring forces and velocity. Muscle function tests included countermovement jump, drop-jumps, isometric mid-thigh pull and isometric bench-press. Body composition was assessed using skin-fold measurements on three occasions and one dual energy X-ray absorptiometry scan. Aerobic capacity was assessed using 2 VO_2 max tests. Leading up to the bout, performance decreased in isometric mid-thigh pull (8%), isometric bench-press (5%), countermovement jump (15%) and impact forces in 3 of 4 punches (4%–7%). Whereas measures of dynamic and isometric muscle function remained depressed or unchanged post competition, punching forces (6%–15%) and aerobic power (6%) increased. Data suggest the athlete may have super-compensated following rest as fatigue dissipated and further adaptation occurred.

ARTICLE HISTORY
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KEYWORDS
Boxing; training camp; physical preparation; tapering; periodisation

Introduction

In recent years, select physiological characteristics of amateur boxers have been reported (Chaabène et al., 2015), including strength and power (Guidetti, Musulin, & Baldari, 2002; Loturco et al., 2015), punching velocity and impact forces (Smith, Dyson, Hale, & Janaway, 2000; Walilko, Viano, & Bir, 2005), aerobic capacity (Bruzas et al., 2014; Guidetti et al., 2002) and body composition (Smith, 2006). However, there is a paucity of information on professional boxers. Popular media commonly reports on amateur boxers who transition into the professional ranks; however, given the large differences in the scoring systems between the two classes, and importantly, the dissimilar number of rounds (3–4 for amateur and 4–12 for professional), it is of interest to the sports science community to understand and profile the physiological characteristics of professional boxers. To our knowledge, no long-term systematic investigations of physical performance adaptations have been reported with either amateur or professional boxers. Cross-sectional, pre–post studies only provide a static picture of an athlete's performance, and this picture may change considerably as a function of when testing is conducted. Indeed, certain fitness qualities are reported to improve and others to degrade during periods of intensified training among athletes from different sporting backgrounds (Costill et al., 1988; Jeukendrup, Hesselink, Snyder, Kuipers, & Keizer, 1992). Conversely, after a period of rest, these same measures can substantially alter once again (Izquierdo et al., 2007; Mujika & Padilla, 2003).

The process of understanding the adaptive response of various physiological measures relevant to sporting performance, and how to optimally prepare athletes to perform, is the foundation for periodised training and the training taper. Notably, there is a paucity of investigations in these areas with boxers, and although these performance variations can be expected to hold true with boxers, there is an added complication of common bodyweight reduction leading up to competitive bouts (Smith, 2006). Thus, the goals of this single-subject case study were twofold. The first was to comprehensively profile the physiological characteristics of a professional boxer for his punching performance, dynamic power and isometric strength qualities, aerobic capacity and body composition. The second was to systematically measure the aforementioned physiological characteristics during and after the preparation phase (including the taper) leading to a state-Title Bout (set for 8 rounds at 76.2 kg), to examine the response of these measures.

Methods

Participant

A professional male boxer (age: 23 years, weight: 80 kg, height: 1.8 m) who competes as a super middleweight

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(76.2 kg) voluntarily agreed to participate. At the time of the investigation his professional fighting record consisted of 5 wins and 0 losses, and his previous amateur boxing career included 70 bouts with 49 wins and 21 losses. The athlete had been training competitively for the past 11 years, and regularly participates in 5–9 training sessions per week (total training hours per week of 7–12 h), in a program that varies with the schedule of upcoming competition. The athlete was provided with a verbal description of the study and an opportunity to clarify any issues before providing written informed consent. The study was approved by the institution's human research ethics committee.

Procedure

The athlete visited the laboratory on 11 occasions: 9 prior, and 2 following the bout. The first session was to familiarise the athlete with all tests and equipment. On 8 subsequent occasions (7 before the bout and 1 after it), the athlete completed a boxing-specific test followed by muscle function tests. Both the boxing and muscle function tests were completed approximately 2 weeks apart, however, at times the frequency was increased to quantify if 3 days of complete rest altered performance (Figures 1 and 2). On two separate occasions the athlete completed a VO_{2Peak} test (49 days before and 10 days

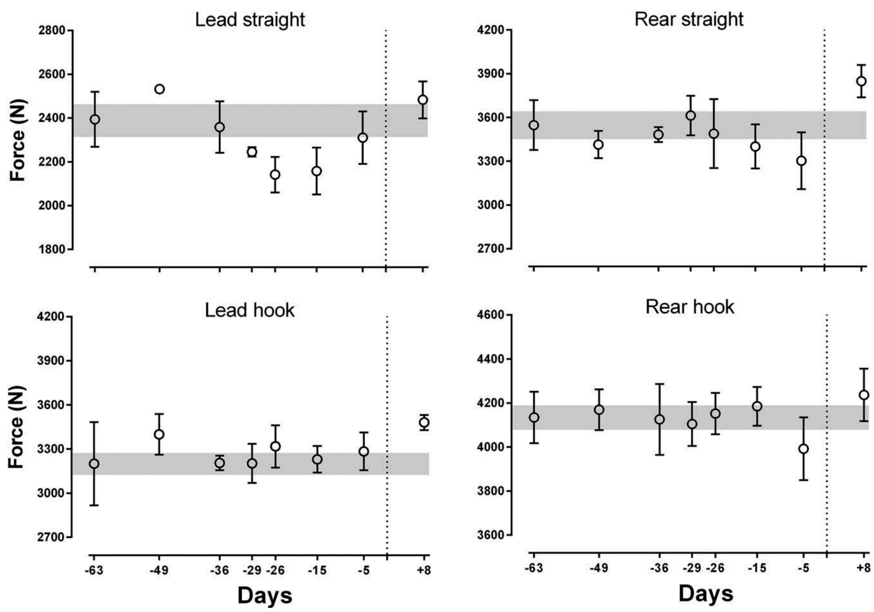

Figure 1. Mean (SD) of punching impact forces during the preparation, tapering and post bout. The dashed vertical line represents the date of the bout, and the horizontal shaded grey region represents the typical error.

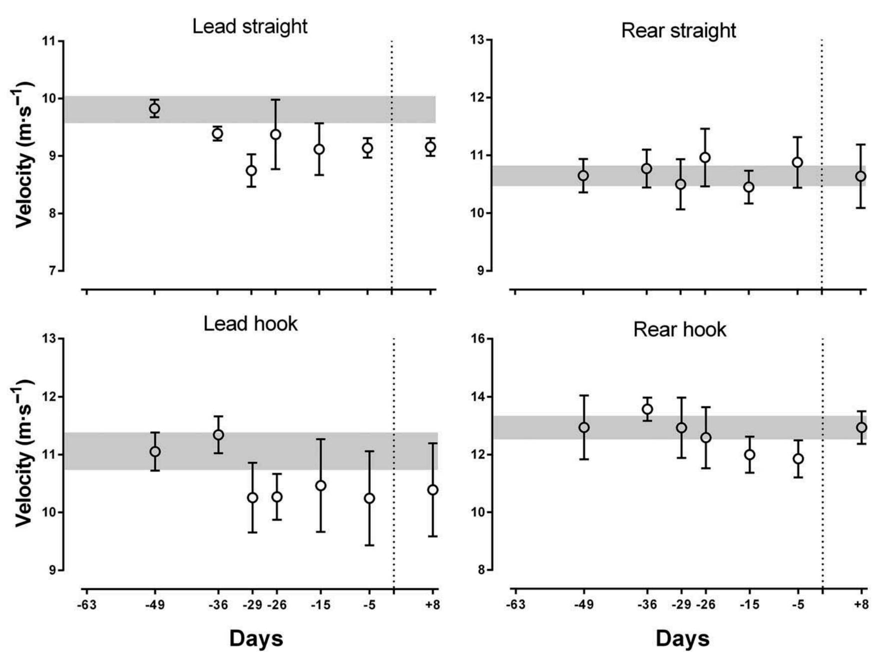

Figure 2. Mean (SD) of punching velocity during the preparation, tapering and post bout. The dashed vertical line represents the date of the bout, and the horizontal shaded grey region represents the typical error.

Table I. A representative illustration of the athlete's training schedule leading up to the Title Bout.

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	Light Sparring 4 × 3 min Heavy bag 4 × 3 min		Light Sparring 4 × 3 min Heavy bag 4 × 3 min		Light Sparring 4 × 3 min Heavy bag 4 × 3 min	Technical drills 45 min Pad work 30 min	Rest
PM	Technical drills 6 × 5 min Heavy bag 4 × 5 min	Technical drills 1 h Pad work 30 min	Light Sparring 8 × 3 min Heavy bag 6 × 4 min Shadow boxing 3 × 3 min	Competition sparring 8 × 3 min Heavy bag 3 × 3 min Shadow boxing 3 × 3 min	Drill work 6 × 5 min Heavy bag 4 × 5 min		

after the bout) and on three occasions his body composition was assessed (49 days and 4 days before and 10 days after the bout); in addition, 7 days prior to the bout a dual energy X-ray absorptiometry (DXA) scan was conducted.

The preparation phase included 8–10 training sessions a week, composed of pad work with the head coach, sparring, bag work, shadow boxing and technical drills (Table I). The athlete completely eliminated specific resistance training from the overall training program during this period. A tapering phase began 10 days before the bout, involving a planned reduction in overall training volume and intensity. With the goal of avoiding complications of rapid weight reductions (cutting), the athlete aimed to gradually alter his body composition to make weight over the entirety of the 8-week preparation period. Training volume was reduced to 5 sessions per week, with an intensity reduction, as reported by the coach and athlete, which required substantially less emphasis on maximal efforts or hard sparring but included training sessions with a greater technical skill focus.

Boxing-specific test

The standard punching performance test used in our laboratory consists of three rounds of 12 maximal effort punches delivered to a punching integrator, with a minute of rest between each round, and begins after completing a self-selected 10- to 15-min warm up. Each round consists of four types of punches delivered three times, in the following order: lead straight, rear straight, lead hook and rear hook with a 5-s pause between each punch. Thus, in a right-hand dominant athlete, the left hand is the lead hand and the right is the rear. The custom built punching integrator is mounted vertically and composed of a load cell with an integrated amplifier (AST brand) bolted to a metal plate, which is covered with a large foam pad wrapped by leather envelope. The raw voltage signal was collected by Data Translation 12-bit USB data acquisition module using QuickDAQ software (Australia) sampling at 1000 Hz and converted to units of force (N). Punch velocity ($m \cdot s^{-1}$) was determined by recording the time interval (Agilent oscilloscope) between two phototransistor infrared LED gates (Vishay) with the first located 0.05 m from the striking surface and the second 0.01 m. Velocity was derived by dividing the inter-gate distance (0.04 m) by the time interval of the two beams being broken. Punch integrator calibration was achieved by dropping a pendulum of a known weight, from a known height, on to the impact surface prior to all data collection. The device's instrumental coefficient of variation was smaller than 1% for both impact force and velocity. The athlete wore the same 16 ounces boxing gloves (Sting) with his own standard under-wraps during testing.

Muscle function tests

Four muscle function tests were conducted in the following order: countermovement jump, drop jumps, isometric mid-thigh pull and isometric bench press. Each test was completed three times with ~1 min of rest between each repetition. All tests were completed on a commercially available portable force plate (9290AD Quattro Jump, Kistler, Switzerland) to record ground reaction forces. Additionally, a single linear position transducer (Ballistic Measurement System, Fitness Technology, Adelaide, Australia) was utilised to measure jump heights. The force plate and a linear position transducer were interfaced with a personal computer via an 8-channel data acquisition system (ADInstruments, Australia) with PowerLab software (ADInstruments, Australia) sampling at 1000 Hz, allowing direct measurement of force–time characteristics. Ground reaction forces and linear position transducer were analysed using PowerLab software and custom macros. Prior to all data collection, the force plate was calibrated using a range of known loads and the linear position transducer was calibrated with a known distance. The athlete performed a similar warm-up prior to all tests, which included self-selected dynamic stretching and two submaximal effort trials per test. Briefly, during the countermovement jump, the athlete was asked to hold a 0.4-kg aluminium bar across his shoulders to which was attached the tether for the linear position transducer and to jump as high as possible. Similarly, during the drop jump the athlete stepped off a 0.4-m box onto the force place with the aluminium bar across his shoulders and was asked to jump as high as possible while minimising contact time. The utilisation of the aluminium bar across the shoulders eliminated arm swing from the movement and thus our outcome measures provide a better reflection of only lower body performance capabilities. The isometric mid-thigh pull was performed with 130° knee angle and corresponding hip angle of 155°–165° prior to pulling the immobile bar in accordance to previous literature (Sheppard, Chapman, & Taylor, 2011). The athlete was then asked to push the ground as hard and fast as possible for a 3-s period. Lastly, a bench was placed on the force plate for the isometric bench press. The athlete lay on the bench with the elbow joints at a 90° angle, the arms at a 45° angle relative to the trunk and was then asked to push the bar as hard and as fast as he could for a 3-s period. Peak concentric forces (N) were recorded for all tests and maximal jump heights for countermovement jump and drop jump.

Aerobic capacity

The VO_{2Peak} test was performed on a custom-built motorised treadmill (AusTredDex, Preston, Victoria, Australia) and involved continuous incremental running starting at 10 km · h^{-1} (0% gradient) and increasing by 2 km · h^{-1} every two minutes until a speed of 16 km · h^{-1} was reached. Thereafter, the gradient increased by 1% every minute until volitional exhaustion. A custom built, automated dual Douglas bag collection system (Saunders, Pyne, Telford, & Hawley, 2004) collected expired gas volumes continuously throughout exercise. Maximal oxygen consumption (VO_{2Peak}) was calculated by adding the two highest consecutive 30-s VO_2 values (Hawley & Zierath, 2004). Heart rate was also recorded continuously using a Polar 800.

Body composition

Anthropometry measures were collected following the International Society for the Advancement of Kinanthropometry (ISAK) guidelines. The sum of seven skin folds (Σ7) were measured by the same certified ISAK level 1 anthropometrist at the triceps, subscapular, biceps, supraspinale, abdominal, front thigh and medial calf sites.

DXA scan was performed and analysed by a trained technician according to the protocol described by Nana, Slater, Hopkins, and Burke (2012).

Data analysis

To determine performance differences between protocols we implemented the general guidelines for data analysis of a single-subject case study design of elite athletes as advocated by Kinugasa (2013). The following data were averaged and presented using distributive statistics (means and SDs): 2 best values for each of the strength/power tests, and best of 6 delivered punches per punch type over the 3 rounds (Figures 1, 2 and 3). When appropriate, Cohen's *d* effect sizes (ES) were calculated for the mean differences between testing days using the pooled standard deviation across days. The magnitudes of these ES were classified as trivial (<0.25), small (0.25–0.50), moderate (0.50–0.10) and large (>0.10) using the scale proposed by Rhea (2004). Linear regressions were calculated for the variables that were measured across the eight sessions to provide an estimate of performance change across time leading to the bout. The correlation magnitudes were classified as trivial (<0.1), small (0.1–0.3), moderate (0.5–0.7) large (>0.7–0.9) and very large (>0.1) using the scale proposed by Hopkins (Hopkins, 2002). Finally, we determined the smallest worthwhile change (smallest meaningful change) for both punch force and velocity to appropriately identify that any differences were of a meaningful magnitude (Hopkins, 2004). The smallest worthwhile change score was calculated by multiplying the overall pooled standard deviation per dependent variable (punch force and punch velocity) across days and conditions by 0.5. This score was compared to the absolute difference between conditions for each day.

Results

The athlete was successful in his super middleweight Australian National Boxing Federation New South Wales professional Title Bout by way of knockout in the first round.

Boxing test

Impact forces

A gradual decrease in impact forces for 3 of the 4 punch types was observed over time as the date of the bout approached (Figure 1). Excluding the post-match time point, small to moderate negative slopes were found in performance in the lead straight (r = 0.67), rear straight (r = 0.56) and rear hook (r = 0.54). Specifically, compared to baseline (–63 days), impact

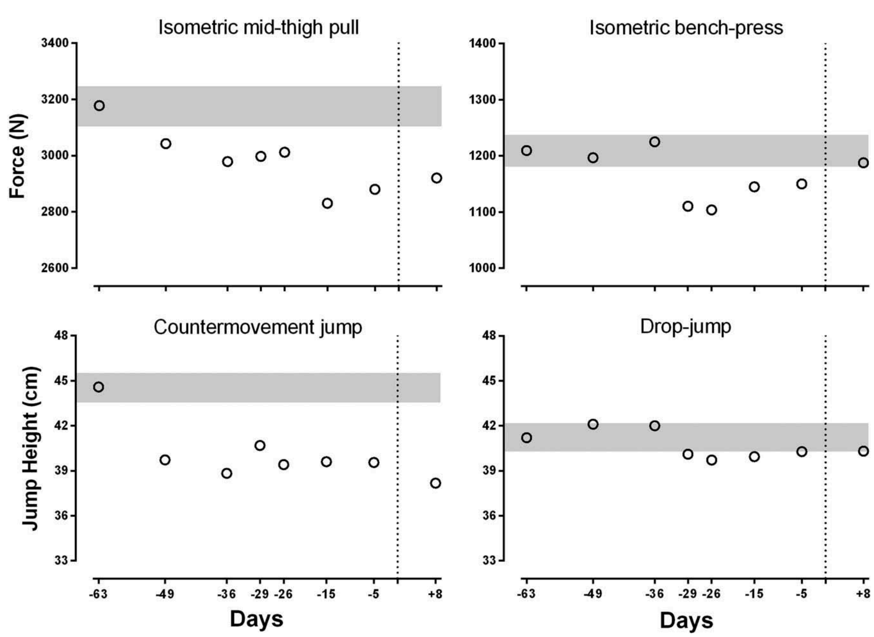

Figure 3. Mean muscle function results during the preparation, tapering and post bout. The dashed vertical line represents the date of the bout, and the horizontal shaded grey region represents the typical error.

forces decreased until pre-match (−5 days) in the following punches: lead straight (4%; ES = 0.68), rear straight (9%; ES = 1.3) and rear hook (3%; ES = 0.83). However, a small improvement was observed for the lead hook (3%; ES = 0.3). Meaningful improvements characterised as greater than the calculated smallest worthwhile change were observed post-bout compared to both baseline and pre-bout values (Figure 1). Specifically, the lead straight improved by 7% (ES = 1.67) compared to pre bout, and by 4% (ES = 0.8) compared to baseline. The rear straight improved by 15% (ES = 3.4) compared to pre bout, and by 7% (ES = 1.3) compared to baseline. The lead hook improved by 7% (ES = 2.0) compared to pre bout, and by 9% (ES = 1.4) compared to baseline. The rear hook improved by 6% (ES = 1.86) compared to pre match, and by 3% (ES = 0.86) compared to baseline.

Velocity

Because of a technical error the data from the first testing day was excluded. Similar to impact forces a gradual decrease in punch velocity prior to impact was observed in 3 of the 4 punch types (Figure 2). Excluding the post bout time point, moderate to strong negative correlations were calculated for performance with the lead straight (r = 0.53), lead hook (r = 0.74) and rear hook (r = 0.86). Furthermore, compared to the testing session at −49 days, velocity continued to decrease to −5 days to the bout in the following punches: lead straight (7%; ES = 3.4), lead hook (7%; ES = 0.38) and rear hook (8%; ES = 1.20), yet no velocity changes were observed with the rear straight. Meaningful improvements were observed post bout compared to some baseline and pre bout tests (Figure 2). Specifically, the lead straight, rear straight and lead hook remained unchanged compared to pre bout. While lead straight (7%; ES = 3.3) and lead hook (4%; ES = 0.1) remained depressed compared to baseline. The rear hook increased (9%; ES = 1.86) compared to pre bout, but was unchanged (>1%) compared to baseline. The reported differences in all of the results were greater than the calculated smallest worthwhile change.

Strength/power tests

Jump height

Countermovement jump height decreased throughout and following the bout (Figure 3), with a negative regression (r = −0.66). While only small differences were observed between pre bout values and post bout (2.5%; ES = 0.28), both were considerably lower compared to baseline (11%–14%; ES = 1.2–1.6). Similarly, drop jump height decreased throughout and after the bout with a negative regression (r = −0.67) (Figure 3A). Only small changes were observed between the pre and post bout (1%; ES = 0.22), with both lower compared to baseline (2%; ES = 0.44–46). Concentric force production in both pre and post bout measures were 6–12% (ES = 0.58–1.1) lower compared to baseline, whereas no changes occurred in concentric velocity (0–2%; ES = 0.09–0.1). Concentric force was decreased throughout the testing period with a negative regression for countermovement jump (r = −0.58) and drop jump (r = −0.44), whereas no relationship was observed with concentric velocity (r ≤ 0.15).

Isometric mid-thigh pull

Isometric force production decreased throughout the monitoring period and in the brief period following the bout, as demonstrated with the large negative relationship (r = −0.82) (Figure 3B). While no meaningful differences were observed between the pre and post bout (1.5%; ES = 0.25), both were considerably lower compared to baseline (7%–9%; ES = 2.1–2.4).

Isometric bench press

Isometric force production decreased over time leading to and following the bout as observed by a small negative relationship (r = −0.35) (Figure 3C). Compared to baseline, force immediately prior to the bout was lower (5%; ES = 0.5), although post bout values were similar (2%; ES = 0.27) to baseline. Small differences were found between the pre and post bout (3%; ES = 0.5) with post bout the greater. Importantly, the observed differences were greater than the calculated smallest worthwhile change.

Aerobic capacity test

At initial testing, the athlete's relative and absolute VO_{2Peak} were 62.3 mL · kg^{-1} and 5.03 L · min^{-1}, respectively. On the second test, 65 days later, his relative and absolute VO_{2Peak} were 66.0 mL · kg^{-1} and 5.25 L · min^{-1}, respectively. Both tests were of approximately the same duration (11:40 vs. 12:00 min). The typical biological variation our laboratory routinely records for this protocol is 2.5%; thus, the recorded improvement of 6% in the second test is greater than the typical test variation (inclusive of biological and mechanical variation) and considered to be a real change. While a plateau in VO_2 was not observed at the cessation of both tests, the recorded respiratory exchange ratio values were 1.175 and 1.145, and the heart rate values were 202 and 200 beats per minute, respectively. These values suggest that maximal effort was attained by the athlete in both tests (Midgley, McNaughton, Polman, & Marchant, 2007).

Body composition

Initial athlete testing for a Σ7 site skinfold measurement was 53.4 mm with a body weight of 80.77 kg, while 5 days prior to the bout his weight decreased to 77.5 kg and the Σ7 skinfold decreased to 45.3 mm. Body mass, as measured by the force plate, indicated that the athlete lost approximately 1 kg every 2 weeks, from baseline to the last testing session prior to the bout. The single DXA scan completed 7 days before the bout indicated a body fat percentage of 10.1%. The post bout body composition assessment indicated an increase in weight from prior to the bout to 79.51 kg, with a concomitant increase in Σ7 skinfold to 50.6 mm.

Discussion

This novel case study reports two unique outcomes: firstly a comprehensive sport-specific physiological profile of a professional boxer and secondly a detailed representation of the preparation and tapering of a professional boxer towards a successful Title Bout. Rarely is the long-term, regular monitoring of a professional athlete's sport-specific physiological characteristics reported, furthermore over a 10-week period in which the training intensity and volume varied between very high to very low.

Physiological profile

The professional athlete's physiological profile was found to be somewhat similar to reported elite amateur boxers (Chaabène et al., 2015). The strength and power measures of the athlete were within the range of results for elite Brazilian amateur boxers (Loturco et al., 2015). Whereas the average maximal countermovement jump height of the reported professional athlete was 0.4 m (range: 0.38–0.44 m), Brazilian athletes averaged 0.37 ± 0.05 m. Given the test's typical error is commonly reported as 0.02 m, we assume that no meaningful differences exist between the investigated athlete and Brazilian boxers. The lack of difference between professional and amateur boxers for strength and power is also evidenced by the comparable isometric bench press forces reported by Loturco et al. (2015) in the Brazilian boxers of 1017 ± 26 N and the professional athlete averaged 1163 N (range 1110–1225 N). This professional boxer's aerobic capacity reached a VO_{2Peak} of 66 ml/kg/min, which is slightly higher than results of elite amateur boxers from various countries which ranged from 59 to 65 $mL \cdot kg^{-1} \cdot min^{-1}$ (Chaabène et al. (2015). We suggest that a more developed aerobic capacity is due to the need to compete successfully over a greater number of rounds in professional boxing compared to amateur boxing. The athlete's body composition as a percent body fat (DXA: 10.1%; Σ7 skinfold 8%–12%) is similar to elite amateur boxers (Chaabène et al., 2015), with an average percent body fat 12% (range 9%–16%) from multiple studies using various techniques.

It is challenging to compare punching performance between laboratories due to differing techniques used to acquire punching impact forces. We recorded a maximal effort rear straight punch with average impact forces of 3500 N, while elite amateur boxers of relatively similar body weights (70 ± 10 kg) are reported to deliver the same punch type with average impact forces of 2650 (Smith, 2006; Walilko et al., 2005) and 4800 N (Smith et al., 2000). The disparity in recorded impact forces can result from differences in author categorisation of athletes as elite, variation due to dissimilar weight divisions, non-standardised boxing gloves and importantly the precision of the measurement system. Interestingly, the result disparity does not appear to be such an issue with punch impact velocities. Previously, Walilko et al. (2005) reported punching velocities of a rear straight punch from seven Olympic boxers across different weight divisions with a mean velocity 9.14 ± 2.06 $m \cdot s^{-1}$. Similarly, the average rear straight punching velocity of this professional boxer was 10.6 ± 0.4 $m \cdot s^{-1}$, and in unpublished data from our laboratory amateur boxers of relatively similar weight divisions (68–78 kg) punch with approximately comparable forces and velocities (5% range) to the investigated athlete. However, the investigated athlete's performance varied substantially during the preparation and the mean velocities are considerably lower compared to peak values achieved on certain days (see Figure 2). This is in contrast to the amateur boxers' results, which represented individual values collected on a single day. Thus, caution is warranted when interpreting outcome measures of boxers in cross-sectional studies, as performance can vary to a large degree as a function of when testing is conducted relative to upcoming matches.

Changes over time

During the preparation phase, decrements in performance leading to the bout were identified with punching impact forces and the strength/power tests. Interestingly, impact forces were considerably greater after 8 days of rest following the bout (7%–15%). Matching the enhanced punching performance was the significant improvement in aerobic capacity recorded 10 days after the bout (6%), despite very limited training during this period. Although VO_{2Peak} was not measured prior to the bout, it can only be speculated that his aerobic capacity followed the same trend as his punches. Nevertheless, we suggest that the athlete supercompensated during the rest period, allowing fatigue to dissipate while accumulated physiological adaptions occurred, which is in line with the general consensus of tapering literature (Bosquet, Montpetit, Arvisais, & Mujika, 2007; Mujika & Padilla, 2003). A similar occurrence is seen in endurance-based sports such as cycling and running, whereby a 7- to 14-day tapering period, which includes a reduction of up to 60% of the overall volume, was found to enhance performance (Bosquet et al., 2007). While the athlete in this case study did not complete any programmed training during the 5 days following the fight, he did perform low level activities such as light jogging and light shadow boxing, which could be considered as either continuation of his pre bout taper or as simple maintenance exercise. The continuous reduction in the strength/power results from baseline to post bout should be considered in relation to the athlete's complete cessation of resistance training during this period. Whereas the athlete was provided with a continuous and adequate stimulus to his boxing skills, the lack of resistance training stimulus for the extended period explains the steady decrease in strength/power performance compared to his post bout–enhanced punching performance.

Our results indicate the possibility that the athlete did not take full advantage of the tapering period. According to the fitness–fatigue model, performance is the sum of positive fitness adaptions and the negative fatigue aspects of training (Chiu & Barnes, 2003). It may be that accumulated fatigue effects from the intense 10-week training period were still present at the time of the bout, thus potentially masking the athlete's peak performance in competition. Although it could be argued that peak performance was not required for him to be successful, the significant enhancement in punching performance post bout can be explained by the further reduction in accumulated fatigue and the maintenance of fitness. The exact individual taper for boxers is difficult to describe with certainty as to our knowledge no studies have investigated tapering with amateur or professional boxers. Especially when considering the expected large inter-individual responses to training (Bouchard et al., 1999; Erskine, Jones, Williams, Stewart, &

Degens, 2010), and the limitations of single case study designs. However, given the dependency on both larger punching impact forces and greater aerobic capacity in boxing matches (Chaabène et al., 2015), as well as their ability to discriminate between level and ranks of boxers (Guidetti et al., 2002; Smith et al., 2000), the substantial improvement observed with the investigated athlete in these measures points to such a possibility.

Two alternative explanations can account for the athlete's decrements in performance. The first is the reduction in body weight (4%) leading up to the bout. Indeed, body weight reduction leading up to competitions is a common procedure among boxers (Morton, Robertson, Sutton, & MacLaren, 2010), and can negatively affect mood and performance (Hall & Lane, 2001). However, considering that the reduction in body weight was not severe and took place over a relatively longer duration, we suggest that this option can only account for a small percentage of the decrements. The second possibility is that the athlete's motivation to complete the tests decreased over time due to fear of injury or fatigue. Yet, our impression throughout the testing period was that the athlete remained very motivated, and that with experience his perception of the tests' safety and non-fatiguing nature allowed for his motivation to remain high.

Based on these data, the athlete and his coach were recommended to consider implementing a longer or different tapering strategy in future preparation phases. However, this recommendation confronts difficulties as boxing-specific training intensity is not well defined and hard to quantify. In contrast to running, cycling or resistance training, where intensity can be defined as a percent of maximum performance (e.g., percent of heart rate or 1RM [repetition maximum]), it is not clear what intensity stands for within boxing training, and importantly, how it should it be measured and monitored. Accordingly, more work is required to answer such questions. Given the growing popularity of combat sports and particularly both amateur and professional boxing, we believe that investigating these questions are of great scientific and practical value.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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