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# Profiling The Physiological Parameters of Boxers in The Parachute Regiment. 'Every Man an Emperor'

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## ABSTRACT

This study aimed to collect and identify the physiological parameters that are required to produce winning performances in an army boxing competition. Army boxing competitions are sanctioned and governed by 'England Boxing' and consist of three rounds of two minutes with one-minute restorative periods. The Parachute Regiment are an elite infantry fighting force within the British military, with a continued success in the inter-army boxing championships. 22 male participants were recruited (mean ± SD age 28 ± 2 years, stature 178 ± 8.1cm, body mass 79 ± 7.1 kg, BMI 24.9 ±2.5). Body fat %, $\dot{V}O_2max$, lower limb power, and 1RM max strength test protocols for back squat and bench press were performed. Additionally, impact punch power measured from rear hand cross strikes, and punching velocities were measured using a linear positional transducer. Countermovement (CMJ) and repetitive (n=10) jump data were collected using a jump mat. The physiological parameters in mean scores; body composition showed body fat 11.8±8.1%: CMJ height 35.5±5cm: Repetitive jump 28.5±5.6cm: Wingate peak power (body mass to power ratio) 11.5±1.6W/kg: Wingate average power, 8.1±1.4W/kg: $\dot{V}O_2max$ 53±4.8 $ml.kg^{-1}.min^{-1}$: Back squat (body mass to weight lifted ratio) 1.95±0.2kg: Bench press 1.1±0.1kg/BW: Rear cross strike velocity 8.47±0.8m/s: Impact power 15227±2250W. Significant relationships were observed between anthropometric data and power, strike velocity and $\dot{V}O_2max$ in addition to relationships being evident between some strength and power variables. by the participants in this study. Although punch impact power is an essential performance indicator in boxing, other physiological factors, such as lower limb power and strength have been demonstrated to attribute to the continued winning performances by 3PARA boxing team.

Keywords: Boxing, training, military, infantry, physiological profiles.

## INTRODUCTION

The British Armed services have employed the art of boxing for many years, its beginnings date back to the 19th Century. The Army Boxing Association (2019) state that the Imperial Services Boxing Association (ISBA) Championships was first introduced in 1919 and made the sport an official contest. The format has since developed and now includes an Inter-Unit Team Boxing competition, which involves seven teams that compete against one another and enter a quarter and semi-finals that lead to the finals, which decides the winner, over an annual season (Johnson, 2019).Boxing involves two combatants that are evenly matched against each other by weight and experience and set in a boxing ring that is sized according to the rules and regulations set by the organising association (Englandboxing.org).

The rules of striking an opponent are restricted to use of hands and must be targeted to connect to the anterior and lateral segments of the head and body, with the aim of stopping the opponent by technical or complete knockout. Many fights (often called bouts) last the entire distance, which is three rounds of two minutes with one minute rest in between and the outcome is then decided on points (Army Boxing Association, 2019; Britisharmyboxing.com, 2019; Englandboxing.org; 2022). Points are scored by the number of destructive blows on target, dependent on their quality of the connection and where they land on the head and body, contests are also won by dominating the bout by technique and competitiveness (Englandboxing.org, 2022).

Rigorous training regimes aim to create adaptations to meet the sport's physiological demands, and the boxer with the best physiological status may have the better chances of winning (Barbosa de Lira eta al., 2013; Carron et al., 2002; Davis et al., 2014; Dunn et al., 2020; Dunn et al., 2021; Turner et al., 2011). However, this describes one variable of many causalities that can effectively achieve a winning outcome of a boxing bout. Other variables such as psychology, technical ability and experience will all play host to giving the boxer the best chance of success (Halperin et al., 2016). Only a few authors to date have investigated physiological profiles of civilian boxers, but none from within the military. The armed service boxer has many other training commitments, such as tactical strength and conditioning and general physical fitness for their battalion, which may interfere with specific periodised programming goals; however, boxing is used as a tool by the services to improve morale and may augment time to the boxer, to train and decree that as a priority over regular military duties (Army Boxing Association, 2019; Johnson, 2019).

During the bouts the work rate is highly anaerobic, however, there is a reliance on the aerobic system to sustain the boxer throughout prolonged use of muscular power and for recovery between rounds (Smith, 2006; Slimani et al., 2017) (see Table 1). With an efficient aerobic system for boxers, body fat percentages are expected to be low (table 2), as aerobic exercise downregulates serum lipids and lipoprotein levels, which would also be advantageous to the boxer due to the strict weight category they fight within (Barbosa de Lira et al., 2013; Pallarés et al., 2016). A highly adapted aerobic system is imperative for withstanding rigorous intermittent exercise, with the higher demands of Phosphocreatine (PCr) replenishment offered to the working muscles (Beachle, 2016). With continuous bouts of a high-intensity workload affecting the aerobic system due to the length of the rounds to rest periods, insufficient time given to completely replenish PCr and convert lactate to pyruvate for use as an energy source, may cause a detrimental effect on performance (Davis et al., 2013). Therefore, identifying the boxer's capability of producing repetitive explosive movements with short recovery periods is essential for success (Rimkus et al., 2019).

**Table 1.** $VO_2$max values of male boxers in previous civilian populations.

| Author | Sample size (n) | Level of boxing | $VO_2$max ml.kg$^{-1}$.min$^{-1}$ |
|---|---|---|---|
| Arseneau et al. (2011) | 9 | National amateur | 62.2±4.1 |
| Basu and Bandyopadhyay (2016) | 40 | National amateur | 59.73±4.81 |
| Bosa de Lira et al. (2013) | 6 | National amateur | 52.2±7.2 |
| Davis et al. (2014) | 10 | National amateur | 59.8±4.3 |
| El-Ashker et al. (2018) | 11 | Novice | 55.45±6.86 |
| El-Ashker and Nasr (2012) | 17 | National amateur | 64.6±7.2 |
| Guidetti et al. (2002) | 8 | National amateur | 57.5±4.7 |
| Kamandulis et al. (2018) | 9 | National amateur | 40.7±2.3 |
| Khannaand Manna (2006) | 12 | National amateur | 61.7±9 |
| Kravitz et al. (2003) | 30 | National amateur | 41.04±6.5 |
| Morton et al. (2010) | 1 | Professional | 61.4 |
| Venckunas et al. (2020) | 11 | International amateur | 63.8±4.8 |
| Smith (2006) | 23 | International amateur | 55.3±6 5.9 |

**Table 2.** Body Fat %values of male boxers in previous civilian populations.

| Author | Sample size (n) | Level of boxing | Body Fat % |
|---|---|---|---|
| Barbosa de Lira et al. (2013) | 6 | National amateur | 12.7±5.3 |
| Basu and Bandyopadhyay (2016) | 40 | National amateur | 8.81±0.98 |
| Bellinger et al. (1997) | 8 | National amateur | 14.4±5.5 |
| Kravitz et al. (2003) | 12 | National amateur | 16.1±7.3 |
| El-Ashker and Nasr (2012) | 17 | National amateur | 14.4±1.9 |
| El-Ashker et al. (2018) | 11 | National amateur | 13.1±1.6 |
| Guidetti,et al. (2002) | 8 | National amateur | 14.5+1.5 |
| Khannaand Manna (2006) | 30 | National amateur | 16.4±3.8 |
| Kamandulis et al. (2018) | 12 | National amateur | 11.5+1.4 |
| Morton et al. (2010) | 1 | Professional | 9.1±2.3 |
| Smith (2006) | 130 | National amateur | 14.5±1.5 |

The anaerobic system is vital in maintaining vigorous workloads when boxing, as such the Wingate cycle test protocol can successfully identify the boxers' anaerobic threshold. The test is performed to absolute fatigue and requires the participant to generate continuous maximum power output, with a 30-second all-out effort (Lenetsky et al., 2018; Lenetsky et al., 2021; Rimkus et al., 2019). Dunn et al. (2021) states a boxer's striking power is reduced when the lower limbs are fatigued and unable to produce the triple extension using muscular force at a continued rate, efficiently enough to produce powerful punches, therefore the Wingate is positively argued for its validity in a physiological testing battery for boxer's (table 3).

The boxer utilises the triple extension whilst performing a punch, where force is initiated from the lower limbs and transmuted through the trunk (often referred to as the muscular box) and executed through the upper limb, producing a forceful strike (Brown et al., 2021). The triple extension is a term used to identify the movement at the joints of the hips, knees and ankles going from flexion into extension when performing most athletic movements such as running, jumping and throwing (Barbosa de Lira et al., 2013). The power produced in the triple extension can be measured by assessing the boxers vertical jump height (table 3), when using force plates or jump mats (Buckthorpe et al., 2012)

Power development derives from muscular strength and the velocity at which it is expressed, with strength being the amount of force the muscular structure can accrue (López-Laval et al., 2020). For the body to produce power for athletic movements, it is suggested by Beachle (2016) a strength base of 1.5 times the body weight in a back squat is attained. Loturco et al. (2016) identified a direct relationship between strength, power and punching impact within well-trained boxers and one of the physiological attributes to winning performances. However, the effective mass of a boxer, defined as muscle stiffening following a second pulse in muscle activation (Ruddock et al., 2016) is imperative when translating force to destructive energy on a target; even if the boxer is at their strongest, the body's ability to withstand reactive force from impact may be deleterious and detrimental to striking impact power (Lenetsky et al., 2015). Therefore, the strength of a boxer needs to be matched by effective mass and a trained boxer that exhibits low strength may still be able to produce higher impact forces on target if they exhibit a high-level reactive strength index (Turner et al., 2011). Table 4 outlines previously published research reporting maximum strength outcomes of boxers.

There are a variety of punching performance analysers that have been used by researchers, (table 5) where a boxer's ability to produce a highly forceful and powerful punch is an essential determining factor of winning (Tuner et al., 2011; Lee and McGill, 2017; Brown et al., 2021; McGill et al., 2010). However, there are a paucity of reliable sensors that accounts for the holistic ecological assessment of punching performances that are of a rigid stable surface that can be punched without causing injury (Lenetsky et al., 2015). Del Vecchio et al. (2013) and Brown et al. (2021) used the PowerKube™ which is a direct measure of impact power that is an integral dynamometer which accounts for accuracy, power, and in its own devised method of using a unit they have coined 'Franklins', measures kinetic energy

**Table 3.** Power values for counter movement jump (CMJ) and Wingate test of male boxers.

| Author | Sample size (n) | Level of boxing | CMJ (centimetres) and Power (watts) |
|---|---|---|---|
| Basu and Bandyopadhyay (2016) | 40 | National amateur | CMJ = 36.33cm + 3.17 |
| Dunn et al. (2020) | 28 | National amateur | CMJ =43cm+5 |
| Loturco et al. (2016) | 9 | National amateur | CMJ = 37.42cm + 4.72 |
| Rimkus et al. (2019) | 8 | National amateur | CMJ = 35cm + 0.04 |
| Khannaand Manna (2006) | 30 | National amateur | Wingate test = 6.5W+5W |
| Popadic et al. (2009) | 14 | National amateur | Wingate test = 6.72+0.86W |

**Table 4.** Strength values of male boxers in previous civilian populations.

| Author | Sample size (n) | Level of boxing | Strength (Body mass to weight lifted ratio) |
|---|---|---|---|
| Khannaand Manna (2006) | 30 | National amateur | BS: 2.05 |
| Loturco et al. (2016) | 9 | Professional | BP:1.57 |
| López-Laval et al. (2020) | 12 | Professional | BP: 0.94 |
| Morton et al. (2010) | 1 | Professional | BP: 0.93<br>BS: 1.01 |

BS = back squat, BP = bench press.

**Table 5.** Punch power impact and velocity values of male boxers in previous civilian populations.

| Author | Sample size (n) | Level of boxing | Striking velocity and power |
|---|---|---|---|
| Brown et al. (2021) | 20 | Professional | Rear hand cross: 22014W±1336<br>Method: PowerKube™ |
| Harris et al. (2020) | 18 | National amateur | Rear hand cross: 7.55m/s + 1.38<br>Method: Accelerometer |
| López-Laval et al. (2020) | 7 | Professional | Rear hand cross: 6.64m/s+0.76<br>Method: Accelerometer |
| Stanely et al. (2018) | 15 | International amateur | Rear hand cross: 6.97 m/s ± 0.86<br>Method: Accelerometer |
| Walilko et al. (2005) | 7 | International amateur | Rear hand cross: 11.9 m/s + 1.4<br>Method: Accelerometer |

(yet to be validated); it is currently being employed by the Ultimate Fighting Challenge (UFC) in Las Vegas and across Asia.

The energetic demands on boxers are met by the energy systems and identifies the use of ATP-CP system at 28%, lactate-glycolysis at 56% and aerobic metabolism with the remaining 16% (Venckunas et al., 2022). Three energy systems are depleted in order of effect, with the initial power stroke up to 6 seconds with the explosive ATP-CP, followed by the latter systems, with low power sustained by the aerobic system. However, the depletion of energy stores will be determined by the intensity and frequency of action. Several researchers (Slimani et al. 2017; Rimkus et al. 2019; Davis, Wittekind and Beneke, 2013; Thomson and Lamb, 2016) quantified the most offensive powerful punch striking techniques used across 3 rounds, identifying the rear hand cross used more than any other power technique and its ability to produce high impact power.

The above sections have highlighted many important factors influencing boxing performances, therefore, identifying and quantifying the physiological profile of athletes in their sport is an ideal method to inform coaches. If practical, a needs analysis, with assessments such as the Wingate, V̇O2max, strength, punching impact power and strike velocities that are detailed in tables 1-5 to determine weaknesses/ strengths in the metabolic pathways; if an athlete's biochemical processes are enhanced, the resultant performance should improve. Therefore, this study aimed to collect and identify the physiological parameters evident in a successful Army boxing team. It was hypothesized strength and punching impact power would be closely correlated and the physiological parameters tested would be superior to those in civilian populations.

## METHODS

*Experimental Approach to the Problem*

This study was carried out to determine the physiological profiles of a military boxing team that had continued winning success at the inter-army boxing championships, giving coaches a better understanding of the needs analysis and improving their programme prescription. All boxing subjects were from the 3PARA regiment boxing team, based in Merville Barracks, Colchester. Ethical approval was granted by the University of East London.

*Subjects*

Twenty-two male participants (mean ± SD age 28±2 years, stature 178±8.1 cm, body mass 79±7.1 kg, BMI 24.9±2.5) that were of national standard, with a minimum of 2 years training experience and fully carded by England Boxing at amateur level, provided written informed consent to participate in the research study. Tests were conducted over two separate visits separated by a 72-hour period. On the first visit the anthropometric, punch impact power/ velocity and jump testing tests were conducted with the Wingate at the end, whilst on the second visit after seventy-two hours recovery, the aerobic ($\dot{V}O_2$max) testing was conducted.

*Procedure*

*Anthropometrics*

Participant's height (Seca 213, Birmingham, UK) and body mass (Seca 761, Birmingham, UK) were measured before testing. Body Fat was measured using Seca mBCA 515 medical body composition analyser (Birmingham, UK) with the method being highly validated and shown to be reliable by Bosy-Westphal et al. (2019) where all participants were instructed to be adequately hydrated prior to testing.

*Aerobic Testing*

Throughout the test, participants' expired gases were measured on a breath-by-breath basis (Cosmed K5; Cosmed, Rome, Italy), to determine $\dot{V}O_2$max. The test started at a 1% gradient and a speed of 10km.h; treadmill speed increased by 2km.h every two minutes until the maximum, self-reported cadence was reached, then remained constant while the gradient was increased by 1% every minute until the participant reached volitional exhaustion. Subsequently, $\dot{V}O_2$max was calculated as the highest $\dot{V}O_2$ achieved during the test, using a rolling 1-minute average. Throughout these testing sessions, laboratory conditions were maintained within a temperature range of 17.5°C to 19.5°C and 35% to 65% relative humidity.

*Anaerobic Power Testing*

Participants completed a 5-minute aerobic warm-up on an exercise bike (Wattbike Pro, Nottingham, UK) at a self-selected intensity, followed by dynamic stretching. Participants then performed a 30-second all-out sprint on the exercise bike, following the Wattbike 30-second sprint program. Peak and average power (Watts) were recorded.

*Strength*

Participants tested using the NSCA 1RM max test protocols for back squat (3/4 depth) and bench press (90degree elbow flexion). Three attempts with 3minute rest in between were conducted, with the maximum lift recorded. Eleiko calibrated bars with Eleiko competition Olympic lifting bumper plates were used.

*Punching Impact Force and velocity*

The participants used the PowerKube™ (Birmingham, U.K) to measure impact power, for three strikes of a rear cross on their dominant hand and the linear positional transducer (LPT) (Chronojump, Spain) identifying velocity. The PowerKubeTM (Strike Research, Norfolk, UK), a commercial impact power measurement tool made for combat sports, was used to quantify the impact power of punching and kicking. The PowerKubeTM is a portable device that weighs 3 kg and is 305 mm by 305 mm by 250 mm deep. It is made of an open-cell foam block placed between two solid surfaces to allow regulated compression. To give immediate data on punching and kicking impact power, two accelerometers implanted in resin are connected to proprietary software (further details on the measurement of impact power are propriety). Previous studies have shown that the PowerKubeTM is a trustworthy tool for measuring striking impact power (ICC=0.98, TEM 3.0%) (Vecchio et al., 2013; Del Vecchio et al., 2021; Gaplin et al., 2015). The strikes were overseen by their boxing coach to ensure safety and correct striking performance. The rear hand strike was analysed due to the high reliance of use during competition (Slimani et al., 2017).

*Jump Testing*

After a five-minute cycle at 60rpm on the Wattbike at level 3 on the airbrake and zero on the magnetic brake, two practice jumps for familiarisation were carried out; after a five-minute rest, three countermovement jumps were performed with hands and the best of three was recorded. The subjects were instructed to place their hands on hips throughout and performed the jump on a standardised contact platform DIN-A3 (Chronojump, Spain) with a 60-second recovery period between jumps. Subjects then performed ten repetitive jumps (RJ) on the multiple jump setting, with hands placed on hips and told to jump on ground contact, to identify sustained jump height mean average.

*Statistical Analysis*

Descriptive statistics for all variables are expressed as a mean ± SD. Statistical analyses were conducted using IBM SPSS Statistics v.26. Data was checked for normality of distribution (Shapiro-Wilk), with all data being normally distributed (p=>0.5). Relationship strength between parameters was assessed using Pearson correlation coefficients and shared variances were also calculated.

## RESULTS

Table 6 illustrates the mean results from the testing battery. $\dot{V}O_2$max, BF%, and Wingate peak values were all comparable to previously published research highlighted in tables 1-5. There appears to be a relatively large variation in CMJ performance, with this population jumping less (range: 1-9cm) than the national amateur standard presented in Table 3. Strength measures relating to BS and BP are equivocal due to the small amount of comparative data i.e., this particular population were comparable to professional boxers and exhibited lower strength values compared to the national amateurs reported in table 4. In table 5, the punching velocities also produced a large variation with no apparent trend, with the boxers in this study closely placed in the midline of the results seen in previous studies. In summary, 3Para boxing team appear to generate similar results found in national amateur fighters.

The strength of relationships between anthropometric data and performance outcomes were calculated and presented in Table 7. Few, moderately strong relationships were established, with weight being significantly related to impact power although the shared variance was just 26%, indicating that other variables make a significant contribution to strike power. Height was significantly related to rear-hand cross velocity but again, the shared variance was low at 23%. Body fat percentage exhibited a significant, negative relationship with repeated jumps indicating higher body fat levels result in lower repeated jump height; the shared variance was also low at just 18%. Unsurprisingly, BF% illustrated a further significant and negative relationship with $\dot{V}O2$max and a shared variance of 24%. All other relationships were deemed to be weak and insignificant; shared variance values highlight many other variables aside from anthropometrics, make significant contributions to performance outcomes.

**Table 6.** Mean results from physiological testing battery of 3PARA boxing team (n=22). Data presented as mean and (standard deviation)

| Body Weight (kg) | Height (cm) | BF % | $VO_2$max ml.kg$^{-1}$. min$^{-1}$ | Back Squat (kg/BM) | Bench Press (kg/BM) | Wingate average (Watts/ BM) | Wingate peak (Watts/ BM) | CMJ (cm) | RJ (cm) | IP (Watts) | CV (m/s) | JV (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 75.68 (10.81) | 177.95 (8.96) | 11.08 (2.84) | 54.44 (4.95) | 1.31 (0.29) | 1.12 (0.18) | 8 (1) | 11 (2) | 33.87 (4.96) | 28.2 (5.46) | 15252 (2079) | 8.60 (0.72) | 7.21 (0.85) |

*BF % = body fat percentage*
*BS = back squat (kg/body mass)*
*BP = bench press (kg/body mass)*
*CMJ = Countermovement Jump height*
*RJ = repetitive jump height*
*IP = Impact power from rear hand cross*
*CV = peak velocity of rear hand cross*
*JV = jab velocity of rear hand*

**Table 7.** Pearson's correlations of anthropometric variables with performance outcomes (n=22). Data presented as correlation (r), shared variance ($r^2$) and level of significance ($p$). Highlighted variables are either significantly (* $p$<0.05) or highly significantly (** $p$<0.01) related.

| | **BS (kg/bm)** | **BS (kg/bm)** | **Wingate Peak (Watts)** | **Wingate Avg (Watts)** | **CMJ (cm)** | **RJ (cm)** | **IP (Watts)** | **Jab velocity (m/s)** | **Cross velocity (m/s)** | **VO2 max (ml/kg/bm)** |
|---|---|---|---|---|---|---|---|---|---|---|
| Weight (kg) | -0.13 | 0.14 | -0.18 | -0.28 | -0.23 | -0.34 | .508* | -0.29 | -0.33 | -0.42 |
| $r^2$ | 0.02 | 0.02 | 0.03 | 0.08 | 0.05 | 0.11 | 0.26 | 0.08 | 0.11 | 0.17 |
| $p$ | 0.57 | 0.52 | 0.41 | 0.21 | 0.30 | 0.13 | 0.02 | 0.19 | 0.13 | 0.05 |
| Height (cm) | 0.17 | 0.13 | -0.07 | -0.30 | -0.18 | -0.18 | 0.37 | -0.41 | -.480* | -0.37 |
| $r^2$ | 0.03 | 0.02 | 0.00 | 0.09 | 0.03 | 0.03 | 0.13 | 0.17 | 0.23 | 0.14 |
| $p$ | 0.45 | 0.56 | 0.76 | 0.17 | 0.43 | 0.43 | 0.09 | 0.06 | 0.02 | 0.09 |
| BF % | -0.13 | 0.24 | -0.05 | -0.13 | -0.21 | -.425* | 0.32 | -0.18 | -0.15 | -.493* |
| $r^2$ | 0.02 | 0.06 | 0.00 | 0.02 | 0.04 | 0.18 | 0.10 | 0.03 | 0.02 | 0.24 |
| $p$ | 0.55 | 0.29 | 0.84 | 0.56 | 0.35 | 0.05 | 0.15 | 0.41 | 0.52 | 0.02 |

*BS: back squat; BP: bench press; CMJ: countermovement jump; RJ: repeated jumps; IP: rear hand impact power; Jab velocity: jab velocity, front hand; Cross velocity: cross velocity, rear hand strike*

**Table 8.** Pearson's correlations for performance variables (n=22). Data presented as correlation (r), shared variance ($r^2$) and level of significance (*p*). Highlighted variables are either significantly (* *p*<0.05) or highly significantly (** *p*<0.01) related.

| | BP (kg/bm) | Wingate Peak (Watts) | Wingate Avg (Watts) | CMJ (cm) | RJ (cm) | IP (Watts) | Jab vel. (m/s) | Cross vel. (m/s) | $VO_2$ max (ml. kg.min) |
|---|---|---|---|---|---|---|---|---|---|
| BS (kg/bm) | .52* | -0.31 | -.520* | -.571** | -0.29 | 0.38 | 0.31 | 0.14 | 0.30 |
| *r²* | 0.27 | 0.10 | 0.27 | 0.33 | 0.08 | 0.14 | 0.09 | 0.02 | 0.09 |
| *p* | 0.01 | 0.16 | 0.01 | <0.01 | 0.19 | 0.08 | 0.16 | 0.54 | 0.17 |
| BP (kg/bm) | | -0.40 | -.500* | -.648** | -.550** | 0.29 | 0.26 | 0.17 | -0.08 |
| *r²* | | 0.16 | 0.25 | 0.42 | 0.30 | 0.08 | 0.07 | 0.03 | 0.01 |
| *p* | | 0.07 | 0.02 | <0.01 | 0.01 | 0.20 | 0.25 | 0.44 | 0.71 |
| Wingate peak (Watts) | | | .910** | .676** | 0.36 | -0.23 | 0.20 | 0.06 | -0.06 |
| *r²* | | | 0.83 | 0.46 | 0.13 | 0.05 | 0.04 | 0.00 | 0.00 |
| *p* | | | <0.01 | <0.01 | 0.10 | 0.30 | 0.38 | 0.80 | 0.80 |
| Wingate Avg (Watts) | | | | .752** | .442* | -0.30 | 0.23 | 0.20 | 0.00 |
| *r²* | | | | 0.57 | 0.20 | 0.09 | 0.05 | 0.04 | 0.00 |
| *p* | | | | <0.01 | 0.04 | 0.18 | 0.30 | 0.36 | 1.00 |
| CMJ (cm) | | | | | .626** | -.459* | -0.21 | -0.10 | 0.16 |
| *r²* | | | | | 0.39 | 0.21 | 0.04 | 0.01 | 0.03 |
| *p* | | | | | <0.01 | 0.03 | 0.36 | 0.67 | 0.47 |
| RJ (cm) | | | | | | -0.33 | -0.32 | 0.06 | 0.11 |
| *r²* | | | | | | 0.11 | 0.10 | 0.00 | 0.01 |
| *p* | | | | | | 0.14 | 0.15 | 0.80 | 0.62 |
| IP (Watts) | | | | | | | 0.17 | 0.17 | 0.02 |
| *r²* | | | | | | | 0.03 | 0.03 | 0.00 |
| *p* | | | | | | | 0.45 | 0.45 | 0.92 |
| Jab vel. (m/s) | | | | | | | | .582** | 0.15 |
| *r²* | | | | | | | | 0.34 | 0.02 |
| *p* | | | | | | | | <0.01 | 0.50 |
| Cross vel. (m/s) | | | | | | | | | 0.16 |
| *r²* | | | | | | | | | 0.03 |
| *p* | | | | | | | | | 0.48 |

*BS: back squat; BP: bench press; CMJ: countermovement jump; RJ: repeated jumps; IP: impact power; Jab vel: jab velocity, front hand; Cross vel: cross velocity, rear hand strike.*

To determine whether there were any other relationships presented within the physiological data, all performance outcomes were correlated. Table 8 illustrates a number of significant, moderate-strong relationships as would be expected. Back squat strength was highly significantly related to bench press scores although the relationship was only moderately strong with a shared variance of 27%. Both strength measures of BP and BS were moderately, but significantly related, to average power output as assessed by the Wingate test. Unsurprisingly, peak Wingate values were strongly and highly significantly related to average Wingate values with a shared variance of 83%. The performance of CMJ was highly significantly related but with moderate strength to BS and BP in additional to peak and average Wingate power, with shared variances ranging from 33-57%. The measure of RJ shared a moderately strong relationship with average Wingate power but just 20% shared variance. Unsurprisingly, RJ shared a moderately strong but highly significant relationship with CMJ. Finally, RJ shared a moderately strong and negative relationship with BP, reaching a highly significant level and a shared variance of 30%. IP shared a significant but moderately strong inverse relationship with CMJ with just a 21% shared variance. Finally, jab velocity and cross velocity shared a highly significant but moderately strong relationship with 34% shared variance which is perhaps unsurprising.

Interestingly, except for the IP: CMJ relationship, all punch-related variables lacked any relationship with the strength and power tests conducted which suggests that BS, BP, lower limb power as assessed by Wingate or jump data make minimal contributions to punch performance in terms of velocity or power within these subjects.

## DISCUSSION

From this study, the participants exhibited enhanced physiological parameters to those seen in civilian-based studies (Tables 1 - 5). Unsurprisingly, $\dot{V}O_2$max moderately correlated with body fat percentages (-.493*), showing the relationship of a high reliance on aerobic activity to produce lower body fat percentages, in line with other studies seen in table 1, which would employ superior oxygen uptake kinetics to the working muscles when producing forceful blows. Body fat percentage is lowered as the effects of a high rate of aerobic training which is seen in this population. A low body fat percentage is deemed advantageous for the boxer due to the weight categories stringent in their application; fat-free mass, or effective mass, has more athletic benefits than fat mass (Rimkus et al., 2019; Lenetsky et al., 2015).

Body fat does not have the capability to produce force; but essentially an energy source for aerobic activity, excess body mass from fat prior to competition could be detrimental to performance as boxing culture accepts aggressive weight cutting prior to weighing in. With up to ten percent in body mass being lost to weight cutting from perspiration, detriments in neuromuscular performance are seen and can be deleterious (Lenetsky et al., 2015). Therefore, with increased fat mass, the boxer would either compete in a higher weight category or aggressively cut weight and lose any benefits expected at fighting below weight (Lee and McGill, 2017; Lenetsky et al., 2018; Lenetsky et al., 2021). Interestingly, the participants in this study did exhibit similar levels of strength to other boxing populations, but weak correlations with impact power and striking velocity within this study of infantry boxers. Although it has been demonstrated by Loturco et al. (2016) strength directly improves striking power output, the lack of correlation could be explained by Lenetsky et al. (2015) and Tuner et al., (2011) where a punch is only as powerful as the effective mass of the body that produces the strike. As 3Para is an amateur team, it is likely that they lack the experience necessary to utilise their effective mass.

To increase muscle stiffness for superior striking destructive power, it is suggested hitting pads and heavy bags would create the adaptations required, which would increase the effects of the stretch-shortening cycle in the upper limbs. The participants in this study produced a mean impact power of 15227W±2250 and when compared to professional boxers by Brown et al., (2021) at 22014W±1336 demonstrating a lower level in striking performance, that can be explained by the experience levels between populations, and poor strength correlations between strength and impact power, as previously mentioned. Professional boxer's rear hand punch velocity of 6.64m/s (López-Laval et al., 2020) and international amateur at 11.9 m/s (Walilko et al., 2005), the boxers in this study were 8.60m/s, perhaps showing no apparent trend (table 5), which would identify the need for more research in this area to identify the relationship between velocity and impact power and other variables that identify the reasoning as to why these differences are seen.

The participants in this study demonstrated effectiveness of the plyometric stretch-shortening cycle and muscle stiffness by producing a repetitive jump (28.5cm) that was only slightly less than a single effort CMJ (35.5cm), coupled with excellent anaerobic power and strength, 3PARA boxing team may attribute their winning performances on their ability to sustain a fighting workload. Winning performances are not just reliant on how much power can be produced by punches, many bouts are decided on points as well as stoppages, therefore it is seen that 3PARA continue to dominate the Inter-Unit Team Boxing competition through technical and tactical superiority and competitiveness through rigorous physiological preparation.

The limitations to this study included a sparsity of comparisons with other study's that used the same equipment used when testing impact power on striking force. Whereas, other authors used wall mounted force platforms that are padded and another study used a mannequin with a force sensor attached to the head part, which did not create a rigid platform to assess a forceful strike, which is needed to correctly assess impact forces (Vagner et al., 2022). More studies to assess punching impact using the PowerKube™ would improve an understanding of a standard of striking performance for coaches to assess, due to its reliability and rigid surface without creating injury. With the ongoing discussion and investigation into a reliable measure of effective mass when striking, the authors from this study could only conclude the reasoning as to low correlations of impact power to strength with assumption, although other studies have stated that low impact forces are created by novice strikers due to less upper limb plyometric ability (Lenetsky et al., 2015; Tuner et al., 2011).

## PRACTICAL APPLICATIONS

With a robust and superior physiological status, boxers will match their performances to that degree, although the variables of technical ability, mindset and experience of the boxer may supersede strength and fitness. However, improvement of the physiological characteristics of an athlete that is specific to their needs will improve their chances of success. Boxing and strength and conditioning coaches should focus on specific strength and power training, focusing on improving the striking velocity with technique, supplemented with aerobic conditioning to improve the recovery rate between rounds. Strength and conditioning should be secondary to technical boxing training but is invaluable and should not be placed on the side-line, for both injury resilience and improved performance; S&C should be placed in a well devised periodised programme that would allow for peaking and recovery for physiological preparedness and readiness for boxing competition.

The parachute regiment boxing team displayed a highly trained physical status, with low correlations to punching performance, indicating that it would be prudent to focus on striking technique within competition preparation that involves striking rigid surfaces such as pads and heavy bags.

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