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AUTHOR
Lonergan, Ben M.; Tallent, Jamie and Lazarczuk, Stephanie

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Needs Analysis of Mixed Martial Arts

Lonergan, B.M[1], Tallent, J[1], Lazarczuk, S.L[1].

[1]School of Sport, Health and Applied Science, St Mary's University, Twickenham, UK

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Address for correspondence:

St Mary's University

Waldegrave Road

Twickenham

TW1 4SX

United Kingdom

Tel: +44 20 8240 4000

Fax: +44 20 8240 4255

Email: ben.longergan@stmarys.ac.uk

BLUF

Physical preparation coaches should ensure that athletes have an efficient aerobic system but success from ground work particularly will come from the ability to produce high anaerobic power.

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Abstract

Mixed marital arts (MMA) is a hybrid of a number of fighting styles. Time motion analysis demonstrates that the high and low intensity work ration of 1:4 appears to be similar to other martial arts such as taekwondo and kick boxing. The intermittent nature of such repeated high intensity work periods suggests that energy is produced by predominantly anaerobic means. This is evidenced with findings of high intensity exchanges lasting no more than 6-14 seconds. However, the aerobic energy system remains important for recovery in aiding removal of lactate, improved oxygen extraction and additional supplementation of anaerobic energy production. Injuries to the head and face are most prevalent, with lacerations and contusions being the leading diagnosis, followed by concussion. Evidence would indicate that more skilled fighters, who are able to end bouts swiftly, as less likely to sustain injury. Musculoskeletal structures need to be accustomed to the high forces and velocities that occur during combat. Practitioners need to ensure that athletes have an efficient aerobic system to last up to 25 mins of competitions. Athletes with higher levels of anaerobic power have demonstrated a greater success in ground based activities. Consequently, the physical preparation of MMA athletes should be multifaceted with the development of a large aerobic base and the ability to reactive explosively essential to success. Athletes also need to train in numerous different individual martial arts leading to a high training load, strength and conditioning sessions consequently needs to be efficient and often minimise training volume.

Key Words

Mixed Martial Arts, Time:Motion Analysis, Force:Velocity, Judo, Brazillian Ju Jitsu, Wrestling

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Introduction

Mixed martial arts (MMA) has been popularised following the birth of the Ultimate Fighting Championship and global television exposure makes MMA a lucrative career option for skilled fighters. MMA is a hybrid of multiple martial arts styles including, but not limited to, brazilian jujitsu (BJJ), muay thai, wrestling, boxing, kickboxing and taekwondo. MMA bouts are normally three to five rounds in length each lasting five minutes in duration (1). The many variations of fighting styles within MMA athletes can be summarised into two broad categories of striking-dominant and grappling-dominant athletes. MMA is intermittent in nature with constant changes of intensity efforts based on the choice of technique, i.e. striking, grappling, and submission tasks (7). In order to achieve victory, MMA athletes must instigate a knockout, submission by the opponent or receive a point's decision from judges which suggests the fighter requires skill in multiple areas. The varying styles of fighters and differing strategies required for each bout will provide unique physical and time-motion characteristics. These should be evaluated by technical coaches in order to formulate optimal strategies for use in strength and conditioning programmes. This article will present key practical training recommendations for a MMA athlete informed by a thorough needs analysis of the sport. Available literature will be utilised to detail the physiological requirements needed to compete at elite levels, with an example weekly training template for an MMA athlete.

Time-Motion Analysis

In order to train successful athletes, coaches should aim to understand time and movement patterns alongside technical and tactical analyses. These are crucial for coaches for athlete preparation and the development of physiological requirements needed for successful combat. Several studies have looked at high and low intensity efforts with low intensity efforts being categorised as time without opposition contact, and high intensity were exchanges between opponents. Miarka et al (1). investigated the technical demands of 351 professional MMA bouts and found that the average ratio between high and low intensity efforts was 1:4 (1). This was based on high intensity periods being 6–14 seconds in duration with low intensity between 15–36 seconds (1). These high intensity durations are of a similar value to those found in taekwondo (2) and kick boxing which were shown to be around 9 seconds (3) creating ratios of between 1:2 and 1:4 (4).

It is said that 90% of energy system contribution of maximal efforts lasting 10 seconds utilises the ATP/PC system, suggesting a critical role for this energy system within MMA (5). With this being said, aerobic fitness levels are still of importance as this system supplements anaerobic energy during exercise and recovery, providing aerobically derived energy at a faster rate (6). Ground-based efforts have not been investigated in MMA, however other grappling-dominant martial arts have been examined. In BJJ ground-based effort had an average of 146 ± 119 seconds, with wrestling averaging 37 ± 10 seconds (7). However, in Judo the effort: pause ratios were different with values of 2:1 or 3:1 which consisted of work phases between 30 and 37 seconds (8). These ratios presented demonstrate: the intermittent nature of MMA; the need for a well-developed aerobic system for recovery; short and long duration anaerobic capacity for maintenance of repeated high intensity efforts; and the differences between fighting styles. Low intensity periods are important for fighters, allowing time to establish positioning, control distance and act as recovery from a high intensity action (9). These ratios are important, enabling coaches to reflect the typical pace and actions used by fighters and to incorporate these variations for fight preparation within individualised programmes.

Total strike attempts per round averaged 40 in professional MMA bouts (1), higher than that found within muay thai where strikes per round averaged 32 (3). Strike volumes of winners and losers differed, with winners having an increased number of actions per bout (1). The average actions displayed by winners per bouts are shown below in Table 1.

Table 1. Average actions per round, performed by winners during MMA contests.
(Adapted from "Comparisons: Technical- Tactical and Time-Motion Analysis of Mixed Martial Arts by Outcomes," by Miarka et al. (1)).

3 x 5 min round efforts	**44-49**	**22-24 attempts**	**28-50 – half guard** **34-37 - side** **13-27 - Front**

Miarka, Brito, Moreira, and Amtmann evaluated 1564 rounds of MMA to assess time-motion analysis of rounds and pacing of strike actions differed depending on round finish (10). Strikes-per-second in high intensity efforts were 1.29, 1.1 and 0.6 in rounds ending in 1st, 2nd and 3rd respectively. This highlights the importance of pacing on successful outcomes. Intra-round comparisons of technical actions demonstrated that losers had fewer total strike and takedown attempts. Winners managed to maintain high intensity and low intensity action ratios with volumes of high intensity efforts increasing in the third round (1). It has been stated that as fights progress to later rounds, ground contact becomes the defining factor for the winners, with increases in advancing half guard, side and back mounts (10). This is similar to Del Vecchio et al. who determined that 50% of fights analysed ended in a ground fighting action which highlights the need for skill and capacity development for success in this action (4). Coaching staff should deliver training which develops the athlete's capacity for work at such rates with these actions.

Aerobic and Anaerobic Qualities

In comparison to other sports with similar worldwide viewing figures, very little research into the physiological profiles of professional fighters is available. MMA fighters require well developed anaerobic capacity to complete repeated high intensity actions such as striking (9). Wingate sprint assessments are used to measure anaerobic power in athletes but to date no published data has included MMA fighters. However, a study using the Wingate test for upper and lower body power in wrestlers found elite junior competitors were able to produce an average output of 611 ± 144 W and non-elite juniors 518 ± 135 W (11). Adult elite wrestlers have produced lower body anaerobic power values of 781 ± 154 W demonstrating discrepancies between professional and amateur levels which were mirrored with upper body values (523 ± 83 W). National level judo athlete anaerobic qualities have been assessed using similar methodology and relative values were established. Mean power was found to be 8.78±0.63 W.kg-1 and Peak Power values were 14.72±0.98 W.kg-1 (12). These increased power outputs in elite ground based athletes suggest this is an important factor for achieving success in grappling-dominant athletes (13).

Lactate accumulation may have negative effects on athletes' performance, but the ability to deal with higher amounts of lactate could be a key determinate of performance. Higher maximum lactate values have been reported in sprint and power athletes versus endurance based athletes and untrained individuals (14). International and national karate athletes performed a run to exhaustion at 140% of VO_2max and found a greater accumulation of blood lactate in the national level fighters (14). The values were 17.9 ± 1.1 vs. 20.7 ± 2.7 mmolL-1 respectively (7). These findings can be a result of increased enhanced by increased buffering capacity of higher endurance trained athletes leading to less lactic acid accumulation (6). Below Table 2 summarises findings from MMA athletes and their blood lactate levels during sparring, MMA specific training and post bout.

Table 2. Lactate ($mmol.L^{-1}$) and RPE values during MMA conditioning.

1	4.3	17.7	16.1	10.5
2	3.5	15.6	18.0	12.2
3	2.4	13.0	13.3	20.7
4	4.8	19.7	14.5	18.7
5	3.8			10.2
6	3.8			19.0

(Note: Adapted from “Lactate and rate of perceived exertion responses of athletes training for and competing in a mixed martial arts event” by Amtmann et al. (15))

Table 3. Training Blood Lactate levels during training in combat athletes.

Boxing (15)	13.6 ± 3.2
Brazillian ju jitsu (16)	10.4 ± 3.6

Freestyle Wrestling (17)	20 ± 0.7
Judo (18)	13 - 18

(Note: Adapted from Heart Rate, Oxygen Consumption and Blood Lactate Responses During Specific Training in Amateur Boxing, Ghosh. (16))

The data presented in Tables 2 and 3 indicate that lactate levels in MMA have similar values to that of grappling based combat sports such as wrestling and judo (15,16). It could, therefore, be concluded that MMA relies on fast glycolytic pathways for energy production during efforts between 30-90 seconds due to the production of lactate (20). MMA bouts last three minutes with one minute of recovery time separating rounds. Therefore, the primary energy supply likely switches mid-round from the anaerobic system to aerobic system, similar to that of Muay Thai athletes (21). High intensity periods have been reported to produce values around VO_2max in an elite athlete population (22) and efforts lasting more than a few seconds will rely primarily on anaerobic glycolysis for energy (6). Lactate recovery typically exceeds 10 minutes therefore the one-minute rest between rounds in MMA suggests recovery will be minimal (23). This highlights that these athletes require a well-developed cardiovascular system and oxidative capacity. An enhanced aerobic capacity is needed for faster recovery between high intensity efforts and increases the rate at which lactate is removed (24). This results in less disruption of muscle pH and creates a more favourable environment for muscle contraction (6) in order to keep rate of force development high.

Elite MMA fighters, professional boxers and Elite wrestlers presented with similar levels of oxidative capacity ranging from (56.8 ± 3.8 $mL.kg^{-1}.min^{-1}$) to (60 $mL.kg^{-1}.min^{-1}$) (23,25,26). Other combat sports have demonstrated lower values, e.g. judo (47.3 ± 10.9 $mL.kg^{-1}.min^{-1}$), and Thai Boxing (48.52 ± 1.7 $mL.kg^{-1}.min^{-1}$) (20, 26). As such, demands for aerobic capacity likely vary dependent on the style of fighter and so training programmes should match this. These VO_2max values presented can be converted to more usable field based measures using the equations below. This value equates in practical terms to a Yo-Yo test result of level 12-13 using the equation:

$$\mathrm{VO_2max} = -23.4 + 5.8\,(\text{speed in km}\cdot\text{h}^{-1})(28)$$

A maximum aerobic speed (MAS) score can also be generated from bleep test results with the equation:

$$\mathrm{MAS} = \text{Final bleep test (speed in km}\cdot\text{h}^{-1})\text{x}\ 1.34 - 2.86\ (29)$$

When testing elite MMA athletes a MAS score of between 4.42 – 4.6 m/s would be desirable based on the data presented in previous studies.

<u>Strength and Power</u>

Improvements in athletic performance have been shown to come from increases in strength and power and are fundamental to success in sporting tasks such as throwing, sprinting and jumping (30). Power is a product of force and velocity and is expressed through many MMA techniques such as striking (high velocity) and grappling manoeuvres (high force) (7). Figure

1 provides an example of variation in force velocity profiles of grappling- and striking-dominant MMA fighters and can help coaches understanding of athletes needs when designing a training programme.

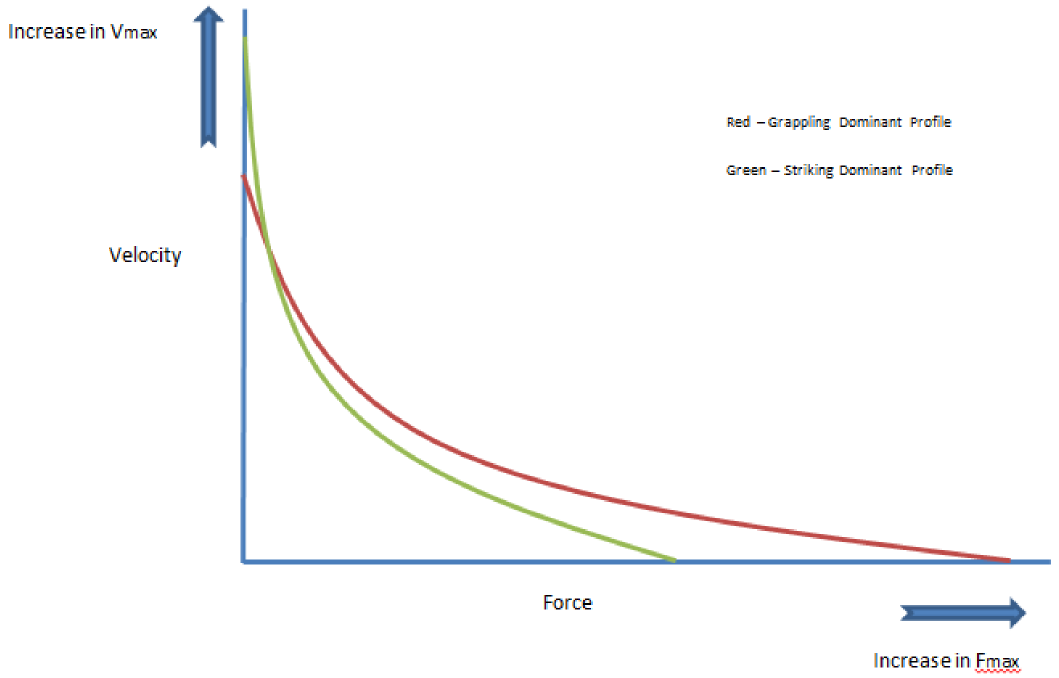

Figure 1. Example force velocity curve of striking and grappling based athletes.

Power has been shown to be highly correlated to vertical jump performance (r = 0.88) (31). Garcia-Pallares, Lopez-Gullon, and Muriel investigated Olympic wrestling performance and found that higher ranked athletes attained significantly higher countermovement jump (CMJ) heights (32) and therefore demonstrated greater power. This can be attributed to the ability of elite athletes to apply a greater amount of force at a given shortening velocity, thereby increasing maximal power capabilities (7). Jump height and power output results between elite and amateur have been summarised in Table 4.

Table 4. CMJ Jump Height and Power Outputs in Elite and Amateur Wrestlers.

Lightweight	35.4 ± 6.7	31.0 ± 3.3	1,568 ± 178	1,407 ± 158
Middleweight	35.0 ± 3.5	31.9 ± 3.8	1,876 ± 141	1,729 ± 168
Heavyweight	35.5 ± 4.4	29.6 ± 3.8	2,244 ± 177	2,074 ± 188

(Note: Adapted from Physical fitness factors to predict male Olympic wrestling performance, Garcia-Pallares. (32)).

Unpressurised time in competition is not a luxury afforded to MMA athletes, so expression of force must happen rapidly. Impact strikes occur within 0.3 seconds of initiation of movement to contact, highlighting the need to develop RFD (33). When more force is applied over a given period, a greater impulse is generated leading to increased momentum and, subsequently, higher power outputs (34). The athlete who can produce more force over that 0.3 second period will, therefore, gain advantage.

Strength is an important quality in enhancing maximal power production (35). Furthermore, lower-body strength increases have been linked with improvements in punching force in boxers (36) and acceleration in karate athletes (37). Strength tests were conducted on 11 male MMA fighters with regional fighting experience and an average body mass of 77.4± 11.4kg. Relative to body weight, these individuals demonstrated bench press and squat outputs of 1.2 ± 0.1 and 1.4 ± 0.1 kg/kg respectively (38). These results were similar to international

Brazilian judo athletes across a range of weight classes where values in these athletes were 1.24 ± 0.11 and 1.44 ± 0.14 kg/kg in the bench press and back squat respectively (39). This suggests that dynamic strength in both the upper and lower body may be a fundamental quality for successful grappling performance. Isometric strength could also be an important quality in grappling and submission exchanges for MMA athletes. Specific strength qualities dictate change in direction ability and include eccentric strength for braking and force absorption, isometric for the plating phase and creating stability; and concentric for propulsion (40). Future studies which further assess these qualities in MMA athletes may complete the picture.

Injury Epidemiology

Examination of competition injuries in MMA provides additional direction for training programmes. The coaches understanding of injury rates and distribution may enable them to implement strategies to target likely areas as part of pre-fight preparation. In professional competitive bouts, the incidence of all injuries has been reported as between 30.8-64.9 injuries per 1000 combat minutes (41,42,43). These most commonly occur in the head/face (18.8-47.9% of total match injuries), the lower extremity (30.4%) and upper extremity regions (10.6-22.7%) (41,42,43). Lacerations and abrasions are the most frequent type of injury occurring in 17.3% to 47.9% of matches (41,42,44) and contusions at 29.4% (43). These are largely unavoidable and therefore there are no specific training options to decrease the incidence of these. Concussion accounts for up to 20% of all injuries (45) which is perhaps unsurprising given the combative nature of the sport, the frequency of injuries to the head and that 29.1% of all bouts end in a KO or TKO (42). Muscle strain injuries accounted for 16.2% of injuries in a combination of male and female fighters who were predominantly amateur (43). Professional or more experienced fighters typically have a lower injury rate than those with less experience (44, 45). However, it is difficult to draw conclusions about necessary risk reduction strategies as no studies have reported severity of injury (i.e. days of activity lost) in these populations.

The loser of bouts was more than twice as likely to sustain an injury as the winner even when variables such as age, weight and fighting experience were controlled for (41). Ngai et al. reported that these variables did not significantly increase the fighter's likelihood of sustaining an injury (41), although Bledsoe et al. reported increasing injury rates with age (42). McClain et al. also established that in bouts ending in submission, decision or disqualification, injury rates were lower than those with a KO or TKO (44). This was particularly the case when a match ended with a strike (44). Ultimately, risk is most likely to be reduced by developing skilled fighters.

Time should also be considered as an important factor in injury risk during competition. Ngai et al. analysed 1270 fighters injury data retrospectively and demonstrated that injury risk rose by 4.2% (Odd ratio = 1.04, $p < 0.01$) for every minute which passed (41). This may suggest a need for training strategies to attempt to negate the potential effects of fatigue as the bout progresses. Longer fights may also provide more opportunity for injuries to occur purely by the nature of the sport. Regardless, this may suggest that the priority for coaches should be to train the athlete to end a bout swiftly.

Practical Applications

The demands of MMA require athletes to be both anaerobic and aerobically efficient, with the aerobic system playing a vital role in the resynthesis of the anaerobic system. Consequently, practitioners and coaches need to ensure training is based around developing a high aerobic capacity, especially for championship fights that can last up to 25 minutes. Tables 5 and 6 provide an example of an athlete's training schedule for both a week-view and individual power session. While the precise structures may vary between athletes, these demonstrate the distribution of both technical and performance training to encompass the multifaceted requirements of MMA mastery. Effort-to-pause ratios appear to be similar to other forms of martial arts used in MMA, therefore these different disciplines should be used to not only to develop the athlete's skills but also the specific physiological requirements of MMA. MMA has similar anaerobic characteristics to ground-based martial arts when compared to 'stand-up' or 'striking' based martial arts. Simply, periods of inactivity are met with extreme periods of high intensity efforts causing high amounts of lactate accumulation. As a result, MMA athletes should ensure they can produce energy quickly but also accommodate a decrease in intracellular pH from lactate accumulation. MMA athletes should also train across the whole force velocity curve, with high force, sustained contraction being evident during grappling and high velocity contractions consistent with striking.

Table 5. An example of a weekly training schedule 2 weeks prior to a fight.

Morning		Speed and Power (med balls, CMJ etc)	Whole Body Strength Training	Rest and recovery	Sparring	Speed and Power	Grappling/Jiu Jitsu	Rest
	Intensity	High	Med-High	-	High	High	High-Mid	-
	Volume	Low	Low	-	Med	Low	Med	-
Midday		Striking Technical	Rest	Rest	Rest	Rest	Rest	Rest
	Intensity	Low-Med	-	-	-	-	-	-
	Volume	Med	-	-	-	-	-	-
Afternoon		Conditioning off feet	MMA – (3 rounds – light striking full wrestling and ground work)	Rest	Wrestling	MMA – Technical Fight PREP	Rest	Rest
	Intensity	High	V-High	-	Med	Low	-	-
	Volume	Low	Med	-	Med	Med	-	-

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Table 6. An example of a power session during the later stages of a fight camp.

Box Jumps	3 sets 3 reps
High Pull	3 sets 5 reps
Supine Medicine Ball Pushes	4 sets 5 reps
Jammer Barbell Throws	4 sets 5 reps (Each Side)
Medicine Ball Rotational Slam	3 sets 5 reps (Each Side)

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