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1 **Needs Analysis of Mixed Martial Arts**

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25

26 **BLUF**

27 Physical preparation coaches should ensure that athletes have an efficient aerobic system but

28 success from ground work particularly will come from the ability to produce high anaerobic

29 power.

30

31

32 **Abstract**

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

51

52 **Key Words**

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

55

56 **Introduction**

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

75

76 **Time-Motion Analysis**

77 In order to train successful athletes, coaches should aim to understand time and movement
78 patterns alongside technical and tactical analyses. These are crucial for coaches for athlete
79 preparation and the development of physiological requirements needed for successful

80 combat. Several studies have looked at high and low intensity efforts with low intensity
81 efforts being categorised as time without opposition contact, and high intensity were
82 exchanges between opponents. Miarka et al (1). investigated the technical demands of 351
83 professional MMA bouts and found that the average ratio between high and low intensity
84 efforts was 1:4 (1). This was based on high intensity periods being 6–14 seconds in duration
85 with low intensity between 15–36 seconds (1). These high intensity durations are of a similar
86 value to those found in taekwondo (2) and kick boxing which were shown to be around 9
87 seconds (3) creating ratios of between 1:2 and 1:4 (4).

88

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

103 by fighters and to incorporate these variations for fight preparation within individualised
104 programmes.

105
106 Total strike attempts per round averaged 40 in professional MMA bouts (1), higher than that
107 found within muay thai where strikes per round averaged 32 (3). Strike volumes of winners
108 and losers differed, with winners having an increased number of actions per bout (1). The
109 average actions displayed by winners per bouts are shown below in Table 1.

110
111 **Table 1.** Average actions per round, performed by winners during MMA contests.

112 (Adapted from “Comparisons: Technical- Tactical and Time-Motion Analysis of Mixed
113 Martial Arts by Outcomes,” by Miarka et al. (1)).

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

114
115 Miarka, Brito, Moreira, and Amtmann evaluated 1564 rounds of MMA to assess time-motion
116 analysis of rounds and pacing of strike actions differed depending on round finish (10).
117 Strikes-per-second in high intensity efforts were 1.29, 1.1 and 0.6 in rounds ending in 1st, 2nd
118 and 3rd respectively. This highlights the importance of pacing on successful outcomes. Intra-
119 round comparisons of technical actions demonstrated that losers had fewer total strike and
120 takedown attempts. Winners managed to maintain high intensity and low intensity action
121 ratios with volumes of high intensity efforts increasing in the third round (1). It has been
122 stated that as fights progress to later rounds, ground contact becomes the defining factor for

123 the winners, with increases in advancing half guard, side and back mounts (10). This is
124 similar to Del Vecchio et al. who determined that 50% of fights analysed ended in a ground
125 fighting action which highlights the need for skill and capacity development for success in
126 this action (4). Coaching staff should deliver training which develops the athlete's capacity
127 for work at such rates with these actions.

128

129 **Aerobic and Anaerobic Qualities**

130 In comparison to other sports with similar worldwide viewing figures, very little research into
131 the physiological profiles of professional fighters is available. MMA fighters require well
132 developed anaerobic capacity to complete repeated high intensity actions such as striking (9).
133 Wingate sprint assessments are used to measure anaerobic power in athletes but to date no
134 published data has included MMA fighters. However, a study using the Wingate test for
135 upper and lower body power in wrestlers found elite junior competitors were able to produce
136 an average output of 611 ± 144 W and non-elite juniors 518 ± 135 W (11). Adult elite
137 wrestlers have produced lower body anaerobic power values of 781 ± 154 W demonstrating
138 discrepancies between professional and amateur levels which were mirrored with upper body
139 values (523 ± 83 W). National level judo athlete anaerobic qualities have been assessed
140 using similar methodology and relative values were established. Mean power was found to be
141 8.78 ± 0.63 W.kg⁻¹ and Peak Power values were 14.72 ± 0.98 W.kg⁻¹ (12). These increased
142 power outputs in elite ground based athletes suggest this is an important factor for achieving
143 success in grappling-dominant athletes (13).

144

145 Lactate accumulation may have negative effects on athletes' performance, but the ability to
146 deal with higher amounts of lactate could be a key determinate of performance. Higher
147 maximum lactate values have been reported in sprint and power athletes versus endurance

148 based athletes and untrained individuals (14). International and national karate athletes
 149 performed a run to exhaustion at 140% of VO₂max and found a greater accumulation of
 150 blood lactate in the national level fighters (14). The values were 17.9 ± 1.1 vs. 20.7 ± 2.7
 151 mmol·L⁻¹ respectively (7). These findings can be a result of increased enhanced by increased
 152 buffering capacity of higher endurance trained athletes leading to less lactic acid
 153 accumulation (6). Below Table 2 summarises findings from MMA athletes and their blood
 154 lactate levels during sparring, MMA specific training and post bout.

155

156 **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

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

159

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

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

Freestyle Wrestling (17)	20 ± 0.7	161
Judo (18)	13 - 18	162

163

164

165

166

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

169

170 The data presented in Tables 2 and 3 indicate that lactate levels in MMA have similar values
171 to that of grappling based combat sports such as wrestling and judo (15,16). It could,
172 therefore, be concluded that MMA relies on fast glycolytic pathways for energy production
173 during efforts between 30-90 seconds due to the production of lactate (20). MMA bouts last
174 three minutes with one minute of recovery time separating rounds. Therefore, the primary
175 energy supply likely switches mid-round from the anaerobic system to aerobic system,
176 similar to that of Muay Thai athletes (21). High intensity periods have been reported to
177 produce values around VO_2 max in an elite athlete population (22) and efforts lasting more
178 than a few seconds will rely primarily on anaerobic glycolysis for energy (6). Lactate
179 recovery typically exceeds 10 minutes therefore the one-minute rest between rounds in MMA
180 suggests recovery will be minimal (23). This highlights that these athletes require a well-
181 developed cardiovascular system and oxidative capacity. An enhanced aerobic capacity is
182 needed for faster recovery between high intensity efforts and increases the rate at which
183 lactate is removed (24). This results in less disruption of muscle pH and creates a more

184 favourable environment for muscle contraction (6) in order to keep rate of force development
185 high.

186
187 Elite MMA fighters, professional boxers and Elite wrestlers presented with similar levels of
188 oxidative capacity ranging from ($56.8 \pm 3.8 \text{ mL.kg}^{-1} \cdot \text{min}^{-1}$) to ($60 \text{ mL.kg}^{-1} \cdot \text{min}^{-1}$)
189 (23,25,26). Other combat sports have demonstrated lower values, e.g. judo (47.3 ± 10.9
190 $\text{mL.kg}^{-1} \cdot \text{min}^{-1}$), and Thai Boxing ($48.52 \pm 1.7 \text{ mL.kg}^{-1} \cdot \text{min}^{-1}$) (20, 26). As such, demands
191 for aerobic capacity likely vary dependent on the style of fighter and so training programmes
192 should match this. These VO_2max values presented can be converted to more usable field
193 based measures using the equations below. This value equates in practical terms to a Yo-Yo
194 test result of level 12-13 using the equation:

$$\text{VO}_2\text{max} = -23.4 + 5.8 (\text{speed in km} \cdot \text{h}^{-1})(28)$$

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

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

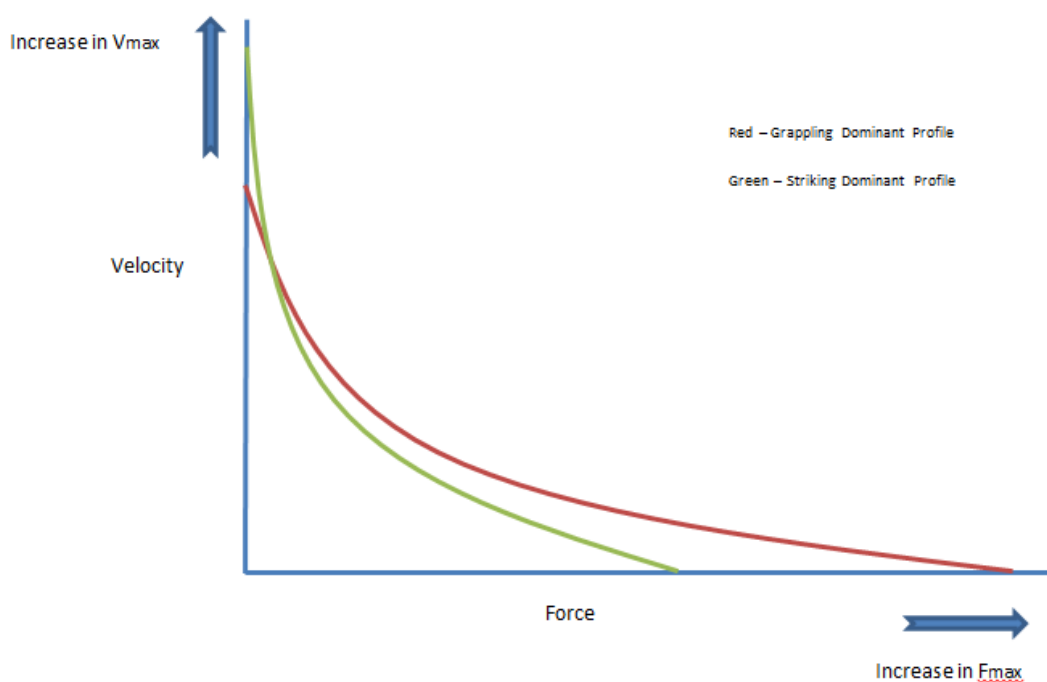
197
198 When testing elite MMA athletes a MAS score of between 4.42 – 4.6 m/s would be desirable
199 based on the data presented in previous studies.

200

201 **Strength and Power**

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

206 1 provides an example of variation in force velocity profiles of grappling- and striking-
207 dominant MMA fighters and can help coaches understanding of athletes needs when
208 designing a training programme.
209



Figure

1.

221 Example force velocity curve of striking and grappling based athletes.

222

223 Power has been shown to be highly correlated to vertical jump performance ($r = 0.88$) (31).

224 Garcia-Pallares, Lopez-Gullon, and Muriel investigated Olympic wrestling performance and

225 found that higher ranked athletes attained significantly higher countermovement jump (CMJ)

226 heights (32) and therefore demonstrated greater power. This can be attributed to the ability of

227 elite athletes to apply a greater amount of force at a given shortening velocity, thereby

228 increasing maximal power capabilities (7). Jump height and power output results between

229 elite and amateur have been summarised in Table 4.

230

231 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

232

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

235

236 Unpressurised time in competition is not a luxury afforded to MMA athletes, so expression of
237 force must happen rapidly. Impact strikes occur within 0.3 seconds of initiation of movement
238 to contact, highlighting the need to develop RFD (33). When more force is applied over a
239 given period, a greater impulse is generated leading to increased momentum and,
240 subsequently, higher power outputs (34). The athlete who can produce more force over that
241 0.3 second period will, therefore, gain advantage.

242

243 Strength is an important quality in enhancing maximal power production (35). Furthermore,
244 lower-body strength increases have been linked with improvements in punching force in
245 boxers (36) and acceleration in karate athletes (37). Strength tests were conducted on 11 male
246 MMA fighters with regional fighting experience and an average body mass of 77.4± 11.4kg.
247 Relative to body weight, these individuals demonstrated bench press and squat outputs of 1.2
248 ± 0.1 and 1.4 ± 0.1 kg/kg respectively (38). These results were similar to international

249 Brazilian judo athletes across a range of weight classes where values in these athletes were
250 1.24 ± 0.11 and 1.44 ± 0.14 kg/kg in the bench press and back squat respectively (39). This
251 suggests that dynamic strength in both the upper and lower body may be a fundamental
252 quality for successful grappling performance. Isometric strength could also be an important
253 quality in grappling and submission exchanges for MMA athletes. Specific strength qualities
254 dictate change in direction ability and include eccentric strength for braking and force
255 absorption, isometric for the plating phase and creating stability; and concentric for
256 propulsion (40). Future studies which further assess these qualities in MMA athletes may
257 complete the picture.

258

259 **Injury Epidemiology**

260 Examination of competition injuries in MMA provides additional direction for training
261 programmes. The coaches understanding of injury rates and distribution may enable them to
262 implement strategies to target likely areas as part of pre-fight preparation. In professional
263 competitive bouts, the incidence of all injuries has been reported as between 30.8-64.9
264 injuries per 1000 combat minutes (41,42,43). These most commonly occur in the head/face
265 (18.8-47.9% of total match injuries), the lower extremity (30.4%) and upper extremity
266 regions (10.6-22.7%) (41,42,43). Lacerations and abrasions are the most frequent type of
267 injury occurring in 17.3% to 47.9% of matches (41,42,44) and contusions at 29.4% (43).
268 These are largely unavoidable and therefore there are no specific training options to decrease
269 the incidence of these. Concussion accounts for up to 20% of all injuries (45) which is
270 perhaps unsurprising given the combative nature of the sport, the frequency of injuries to the
271 head and that 29.1% of all bouts end in a KO or TKO (42). Muscle strain injuries accounted
272 for 16.2% of injuries in a combination of male and female fighters who were predominantly

273 amateur (43). Professional or more experienced fighters typically have a lower injury rate
274 than those with less experience (44, 45). However, it is difficult to draw conclusions about
275 necessary risk reduction strategies as no studies have reported severity of injury (i.e. days of
276 activity lost) in these populations.

277

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

286

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

294

295 **Practical Applications**

296 The demands of MMA require athletes to be both anaerobic and aerobically efficient, with
297 the aerobic system playing a vital role in the resynthesis of the anaerobic system.
298 Consequently, practitioners and coaches need to ensure training is based around developing a
299 high aerobic capacity, especially for championship fights that can last up to 25 minutes.
300 Tables 5 and 6 provide an example of an athlete's training schedule for both a week-view and
301 individual power session. While the precise structures may vary between athletes, these
302 demonstrate the distribution of both technical and performance training to encompass the
303 multifaceted requirements of MMA mastery. Effort-to-pause ratios appear to be similar to
304 other forms of martial arts used in MMA, therefore these different disciplines should be used
305 to not only to develop the athlete's skills but also the specific physiological requirements of
306 MMA. MMA has similar anaerobic characteristics to ground-based martial arts when
307 compared to 'stand-up' or 'striking' based martial arts. Simply, periods of inactivity are met
308 with extreme periods of high intensity efforts causing high amounts of lactate accumulation.
309 As a result, MMA athletes should ensure they can produce energy quickly but also
310 accommodate a decrease in intracellular pH from lactate accumulation. MMA athletes should
311 also train across the whole force velocity curve, with high force, sustained contraction being
312 evident during grappling and high velocity contractions consistent with striking.
313

314 **Table 5.** An example of a weekly training schedule 2 weeks prior to a fight.
 315

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	-	-

316

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

318		
Box Jumps	3 sets 3 reps	320
High Pull	3 sets 5 reps	321
Supine Medicine Ball Pushes	4 sets 5 reps	322
Jammer Barbell Throws	4 sets 5 reps (Each Side)	323
Medicine Ball Rotational Slam	3 sets 5 reps (Each Side)	324

325

326

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