ANTHROPOMETRIC AND PHYSICAL CHARACTERISTICS OF MIXED MARTIAL ART ATHLETES

By

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The primary purpose of this project was to describe the anthropometric and physical characteristics of MMA fighters to establish a reference for their athletic profile, focusing on: somatotyping, skill-related physical fitness test components, and muscular fitness tests, which would provide basic guidelines to help coaches and athletes develop training goals. A total of 30 subjects, 13 amateurs and 17 elites competitive male MMA fighters volunteered for this project. The battery of performance tests was administered by sports scientist outside of a laboratory setting. Measures included: mean somatotype (3.4-6.2-1.9) characterized as endomorphic-mesomorph; age: 26.0 ± 6.0 years; height:177.0 ± 8.0 cm; body mass: 80.8 ± 12.9 kg; %BF: 9.7 ± 2.5 %; mean 1RM/BM for bench press: 1.34 ± 0.2, back squat: 1.8 ± 0.2 and weighted chin-up: 0.7 ± 0.2; combined grip strength: 110.2 ± 22.8 kg; and pull-up test: 20.1 ± 4.2 repetitions. Descriptive data was used to generate reference values for MMA fighters by classifying them into high, medium, and low rankings. When assessing the skill-related performance tests using k-mean cluster analysis, two groups were formed (Cluster 1: 6 amateurs and 2 elites; Cluster 2: 7 amateurs and 15 elites). The fighters in Cluster 2 scored significantly ($p < .05$) better than those in Cluster 1 in all of these tests. In
addition, an independent t-test revealed that elite fighters had significantly better scores than amateurs for agility, power, and coordination. This may suggest that these three performance tests are good indicators for the sport demands of MMA.
ACKNOWLEDGEMENTS

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INTRODUCTION

Mixed Martial Arts (MMA) is a full contact sport that allows the use of grappling and striking techniques, either standing or on the ground. Its varied sub-sport components involve mainly kickboxing, boxing, karate, tae kwon do, judo, greco-roman wrestling, freestyle wrestling, Brazilian jiu jitsu and other styles (Alm & Yu, 2013; Amtmann, Amtmann, & Spath, 2008; Tota, et al., 2014). The earliest known depiction of combative entertainment was seen in 2300 BC, hence combat entertainment is one of the oldest sports in history and deserves the attention from science (Buse, 2006).

In 1993 the Ultimate Fighting Championship (UFC) was introduced in Denver Colorado, and in 2001, Lorenzo Fertitta (Chairman/CEO) and his older brother Frank, along with high school friend Dana White (President), paid $2 million for a nearly bankrupt company that organized mixed martial arts fights (#1275 Lorenzo Fertitta, 2016). Today White is President of the UFC and the Fertitta brothers control the UFC’s parent company, Zuffa. The UFC is now one of the fastest growing sports in the World and broadcasts to more than 1 billion homes in 30 languages across 149 countries (#1275 Lorenzo Fertitta, 2016). White revealed to the Financial Times in March 25, 2014 that the UFC is worth close to 3.5 billion. The UFC’s first show sanctioned by the Nevada Athletic Commission (NAC) had gross sales of $816,600.00 with a crowd of 7,238 people in 2001, which in 2015 peaked at $10,006,249.00 with a crowd of 15,648 at Connor McGregor vs. Jose Aldo main event (Nevada’s Top 35 MMA Gates, 2016).
In 2012 Dana White (UFC President) confirmed the UFC would feature women’s MMA, signing its first female fighter, Ronda Rousey (Gross, 2012). She became the first UFC female champion. The now supremely dominant organization in martial arts had, as its initial goal, to showcase to the world which martial arts discipline was most effective in a fight (Alm & Yu, 2013). With time, the sport evolved as martial artists started to incorporate various different martial arts into their skill set, which gave birth to MMA. The organization has nine weight divisions currently.

The mental and physical skills required to master various traditional martial art training influences the athlete’s foundational mental and fitness characteristics (Siqueido, 2010). The only martial art that is heavily influenced in school systems is wrestling, which gives wrestlers an edge of athleticism and performance education at an early age. Currently six out of the eight current champions in the world’s largest MMA organization (UFC) come from a wrestling background, and the two that do not have the best wrestling defense.

According to Mirzaei, Curby, Rahmani-Nia, and Moghadi (2009) somatotyping, which measures body shape and size, plays an important role in the self-selection of individuals for competitive sports. There is a considerable amount of information in the sport science literature regarding the suitability of various body types, not only for particular sports but also for specific events or positions within some sports. In combat sports, the body shape of the athlete allows us to identify different performance levels, determine the achievement of top performance and impact on the application of different techniques, linked to motor abilities, and ideal body weights and body compositions for
specific sports (Baez et al., 2014; Casals, Drid, Stojanović, Drapšin, & Ostojić, 2014; Franchini, Sterkowicz-Przybycien, & Takito 2014; Noh et al., 2014; Pieter, Bercades, & Center, 2009; Sterkowicz-Przybycień, Sterkowicz, & Żarów, 2011).

Hoffman (2011) states that development of an evidence-based training program is connected to the needs analysis of a sport and, to understand the basic physical requirements of a sport, an athletic profile must be developed. The development of this profile requires a detailed battery of testing that provides a thorough analysis of all components comprising athletic performance (i.e., strength, endurance, anaerobic power, speed, agility, balance, coordination, reaction time, maximal aerobic capacity, and body composition). This project, along with previous studies, may fill the gaps in the literature… helping to aid in the development of an athletic profile that may allow: better judging of the effectiveness of a training plan; optimization of overall physical and mental preparation for competition day; evaluation of potential for overtraining or undertraining (overtraining syndrome); identification of strengths and weaknesses in order to create training objectives; and classification of skill status, body type, and ability level.
Mixed Martial Arts

Mixed Martial Arts (MMA) is a combat sport that allows the use of grappling (submission wrestling) and striking (e.g., punching, kicking, kneeing, and elbows) techniques, either standing or on the ground in a ring or fenced cage of the shape of an octagon (Lenetsky & Harris, 2012; Siqueido, 2010). Its varied sub-sport components involve mainly kickboxing, boxing, karate, tae kwon do, judo, Greco-roman wrestling, freestyle wrestling, and Brazilian jiu jitsu (Bounty, 2011; James, Kelly, and Beckman, 2013; Tack, 2013). Each bout can be extremely different depending on the athlete and his or her opponent. During the 1900’s MMA contests took place in Europe and Japan (Buse, 2006). Bruce Lee is one of the first well known martial artists turned movie star to study various martial arts and form them into one. This was a pivotal point in the evolution of MMA because it was considered erroneous to mix martial arts and teach sacred martial arts to outsiders.

MMA Rules

A fighter may win by decision (judges give majority points to winner), knockout (rendered unconscious), technical knockout (stoppage by referee or professional medical staff), submission (choke or joint manipulation), and forfeit (fighter shouts or taps canvas, opponent, or themselves 3 times) or disqualification from opponent. In the amateur settings there are three rounds lasting 3 minutes each, and in a professional bout
there are three rounds lasting 5 minutes each, with both level of fighters having a 1-minute break in between rounds. Besides the difference in duration time of the rounds in amateur compared to professional, in amateur competition the athletes are not allowed elbows or knees to the head depending on agreed rules. However, during championship bouts in either amateur or professional settings, a fight is extended to 5 rounds.

To be successful in MMA, athletes need experience and extensive training in striking and grappling, especially at the elite level. Grappling, striking, and aggression are judged in competition by three judges. Judges use the ten-point system with the three judges scoring each round, the winner of each round receives ten points while the loser receives nine points or fewer. Scores of 10-8 are typically awarded for dominant rounds and anything more dominant is scored less, like a 10-7 round, which is very rare.

Common Injuries in MMA

Common injuries in MMA according to Tack (2013) include “upper limb (22.7%); head, neck, and face (32%); and lower limb (30.4%), with most occurring in training and predominately to the defending fighter”. Injuries seen in the subcomponents sports that are heavily incorporated in MMA are: shoulder, elbow, back, and neck injuries (boxing); knee, shoulder, ankle, and neck injuries (wrestling); and knee, elbow, foot, hand, face, and rib injuries (kickboxing) (Tack, 2013). In MMA, there are many joint locks that attack the neck, shoulder, spine, elbow, wrist, hip, knee, and ankle-- making all these potential sites for injury. It’s important to be aware of common injuries in MMA
and its subcomponent sports for prehabilitation to help in injury prevention strategies.

Amtmann and Berry (2003) address the fact that MMA athletes have high potential for overtraining due to its training intensity in multiple combat sports, thus the risk of musculoskeletal injury increases for all levels of athletes increasing exercise, physical activity, intensity, and duration (many top competitors perform sport training 3 times a day, 5-7 days a week).

Another issue relevant for strikers and MMA is disproportionality. This muscle imbalance is due to the dominant utilization of the anterior musculature in strikers (as opposed to the posterior musculature), causing possible high risk of injuries due to imbalances (Amtmann & Berry, 2003). Bodden, Needham, and Chockalingam (2015) and Amtmann and Berry (2003) assert that, because wrestling has one of the top injury sites at the neck and spine, improved neck and back strength exercises may prevent injury in MMA athletes. Lastly, because MMA is a weight-class sport, rapid weight loss is a major concern and can lead to dehydration-related health issues that may impair performance or even worse, possible death (Jetton et al., 2013). Thus, guidelines on weight management may help prevent acute dehydration in MMA athletes.

Physical Fitness Characteristics of Mixed Martial Artist

Despite the UFC’s fast growing popularity, MMA has generated very little scientific research, which is strange since the sport has grown exponentially in a short period of time (Alm & Yu, 2013; Amtmann, Amtmann, & Spath, 2008; Schick et al.,
There’s a lack of scientific research on MMA compared to other mainstream sports, and especially compared to other combat sports like wrestling, judo, and boxing (Alm & Yu, 2013; Amtmann, Amtmann, & Spath, 2008; Schick et al., 2010; Siqueido, 2010; Tota, et al., 2014).

MMA appears to be an intermittent physically demanding sport with short phases of maximal or supra-maximal intensity spaced by brief recoveries; therefore, it is likely that all three energy systems (phosphagen, glycolytic and mitochondrial respiration energy systems) are recruited during a match. MMA also requires complex skills and tactical excellence for success; however, to the best of our knowledge, in the absence of national physical fitness standards for MMA fighters, it is up to each gym owner or coach to ensure that their athlete is fit with regard to health and skill-related physical fitness. To help the sport grow further, many professionals agree there needs to be a complete and validated physiological profile on MMA athletes (James, et al., 2013; La Bounty et al., 2011; Lenetsky & Harris, 2012; Tack, 2013).

Literature

This paper includes a review of literature summarizing the descriptive physical characteristics on MMA athletes. Relevant papers were identified and selected using mostly Medicine and Science in Sports Exercise and the Journal of Strength and Conditioning Research, searching journal articles and reference lists, and World Wide Web searches using Google Scholar search engine identifying key databases and online
journals. We summarized 8 original investigations focused on MMA athletes (1 case study, 1 thesis, 2 journals, and 4 abstracts) and a grand total of 23 investigations on MMA and other combat sport athletes on their anthropometrics and physical and physiological characteristics. We limited our search to MMA, combat sports, somatotype, and performance testing. Most MMA studies involved amateur male subjects; researchers described anthropometrics, health-related physical fitness test components, and power and agility. Tables 1 to Table 7 summarize studies in which MMA athletes are described and the missing literature on somatotype and the majority of the skill-related physical fitness components, which are all pertinent when developing an athletic profile.

Somatotype

History of somatotyping

Noh et al. (2014) discusses that Hippocrates around 400 BC recognized two types of human somatotype: habitus phthisicus and habitus apoplecticus. Habitus phthisicus means “long and thin,” and habitus apoplecticus means “short and thick” (Noh et al., 2014). This was the origin of the concept of somatotype. However, it was impossible to define standardized somatotype characteristics, as there were differences according to active lifestyles, until the Heath-Carter method came into existence. Carter (2002) defined somatotype as “the quantification of the present shape and composition of the human body”.

Carter’s method ascertains somatotype according to the size of the body, bone width, and skin thickness. This method classifies individuals into 13 somatotypes based on the results of these measurements (Carter, 2002; Noh et al., 2014). This classification suggests that acquired behavior and lifestyles could have an effect on body shape, as well as genetics.

There are three basic human body types: the endomorph, characterized by a dominance of body fat and relative fatness; the mesomorph, marked by a well-developed musculature and relative musculo-skeletal robustness; and the ectomorph, distinguished by a lack of much fat or muscle tissue and relative linearity or slenderness of a body build (Carter, 2002).

**Sport benefits of somatotyping**

Heath-Carter’s classification can be applied to amateur or elite athletes. Researchers have shown that the adaptation to physical effort as a result of training and the process of selection results in a decrease in somatotype diversity among athletes in similar sports or athletes using similar skills compared with nonathletes (Baez et al., 2014; Casals, Drid, Stojanović, Drapšin, & Ostojić, 2014; Franchini, Sterkowicz-Przybycien, & Takito 2014; Mirzaei et al., 2009; Noh et al., 2014). Mirzaei et al. (2009) states that somatotype, combined with other capacities, such as body composition, proportionality, strength, power, flexibility, speed, and agility, is an indicator of the suitability of the athlete to perform at a high level. However, in the wider performance context, the level of skill, cardiovascular fitness, and psychological profile of the athlete
must also be carefully considered (Baez, 2014; Casals et al., 2014; Noh et al., 2014; Pieter, Bercades, & Center, 2009). Body shape plays an important role in the self-selection of individuals for competitive sports. There is also a considerable amount of information in the sport science literature regarding the suitability of various body types, not only for particular sports but also for specific events or positions within some sports. It is widely believed by competitors and coaches that there are ideal body weights and body compositions for specific sports (Baez, 2014; Casals et al., 2014; Noh et al., 2014; Vernillo et al., 2013).

**Somatotyping of combat sports heavily incorporated in MMA**

Reported mean values for combat sport somatotype can be found across age groups in Table 1 (Baez et al., 2014; Casals et al., 2014; Franchini et al., 2014; Mirzaei et al., 2009; Noh et al., 2014; Sterkowicz-Przybycień et al., 2011; Zabukovec & Tiidus, 1995). Baez et al. (2014) studied the somatotype of 25 elite male Brazilian Jiu Jitsu practitioners. The athletes were measured according to the Heath-Carter method and were categorized as elite (purple, brown, black = 3 highest levels). Average somatotype reported for ages 26.31 ± 5.58 years was 2.23–6.33–1.75, which is characterized as balanced mesomorph (Baez et al., 2014). Casals et al. (2014) investigated the somatotype of 100 (34 females and 66 males) elite level Judokas in 7 different weight classes using the protocol developed by the International Society for Advanced of Kinanthropometry (ISAK) (Marfell-Jones, Olds, & Stewart et al., 2006). The evidence Casals et al. (2014) found suggests that there are specific somatotypes for each weight division in elite
judokas. Light weight judo athletes were characterized as mesomorphic and ectomorphic, with an increase in the dominance of mesomorphomic and endomorphic components in heavier weight divisions (Casals et al., 2014).

Franchini et al. (2014) measured 104 male Judoka athletes of 7 different weight divisions. The Brazilian judo athletes sampled competed at international and national levels and had a mean somatotype value of 3.6-6.4-1.5, which is characterized as endomorphic-mesomorph. This somatotype was typical in three middle and two heaviest weight divisions, however, it was not the case for the 60 kg (2.3-5.2-2.2) and 66 kg (2.3-5.2-2.3) weight classes. Somatopoints for these latter groups were balanced-mesomorph; somatotype categories were similar in the three lightest groups (60 kg, 66 kg, 73kg), while the heaviest category differed from all other groups; most of the differences among groups appeared in the bone breadth measurements (Franchini et al., 2014). Thus, the main differences between weight categories were in the bone breadths and circumferences, whilst height and skinfold thickness are variables best differentiated those in heavier from the lighter categories (Franchini et al., 2014).

Mirzaei et al. (2009) studied the somatotype of 70 male elite Wrestlers with an average age of 19.8 ± 0.9 years and found mesomorphy characteristics. Noh et al. (2014) investigated the somatotyes for 23 male elite boxers and 23 male nonathletes. The average age of the elite boxers studied was 19.3 ± 0.3 years with a mean somatotype of 2.3-3.7-2.3 (Noh et al., 2014). The nonathletes averaged 22.6 ± 0.6 years with a mean somatotype of 3.0 -3.0-2.6. The researchers summarized that the elite boxers had a higher mesomorphic component and a lower endomorphic component for their athletic
performance (Noh et al., 2014). Therefore, Noh et al. (2014) suggested that elite boxing athletes who are injured or training for a match need to be training for fat reduction and muscle power when returning from injury.

Sterkowicz-Przybycień et al. (2011) studied 23 male wrestlers 24.9 ± 5.5 years: heavier weight division (n=12); lighter weight division (n=11); {12 = Olympic qualifications tournament, 6 = Olympic games}. The researchers found somatotype characteristics for heavier wrestlers were endomorphmesomorph, whereas lighter weight divisions were dominated by balanced mesomorph. Sterkowicz-Przybycień et al. (2011) also reported that those athletes with higher levels of sports experience had lower endomorphy (i.e., tendencies for lower fat content) and had pelvis/shoulder ratios that were interrelated with higher competition level presented by the wrestlers. Sterkowicz-Przybycień et al. (2011) found wrestlers in total were similar to untrained subjects, categorized as endomorphic mesomorph, demonstrating a range of specific characteristics in body build that is connected with the demands of training and competition. With regard to somatotype, which is a synthetic approach to body build, a considerable advantage of wrestlers over the untrained occurs in mesomorphy, whereas lower values are observed for endomorphy and ectomorphy (Sterkowicz-Przybycień et al., 2011).

Zabukovec and Tiidus (1995) studied somatotype of four male elite kickboxers who were on average 27 (range 22-31) years old. Mean somatotype using the Carter method was 2.6 (range 1.5-4.0), 4.3 (range 4.0-4.5), 2.5 (range 2.0-3.5) which is characterized as mesomedial body type. Zabukovec and Tiidus (1995) summarized by stating that the values found “suggest that lean mesomorphic body types are vital for
success in kickboxing (and other combat sports) which encourage athletes to minimize their body fat in order to qualify for in the lowest weight category possible”. However, to the best of our knowledge no research on somatotyping of amateur or elite MMA athletes has been done, seen in Table 1.
Table 1. Somatotypes of Combat Sport Athletes and Martial Artists

<table>
<thead>
<tr>
<th>MARTIAL ART</th>
<th>PROTOCOL</th>
<th>n (Sex)</th>
<th>AGE</th>
<th>LEVEL</th>
<th>RESULTS</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazilian Jiu Jitsu</td>
<td>Heath-Carter</td>
<td>25 M</td>
<td>26.31 ± 5.58</td>
<td>elite</td>
<td>2.2-6.3-1.8 = balanced mesomorph</td>
<td>Baez et al. (2014)</td>
</tr>
<tr>
<td>Judoka</td>
<td>Heath-Carter</td>
<td>34F/66M</td>
<td>elite</td>
<td>N/A</td>
<td>heavier = mesomorphic-endomorphic lower = mesomorphic-endomorphic</td>
<td>Casals et al. (2014)</td>
</tr>
<tr>
<td>Judoka</td>
<td>Heath-Carter</td>
<td>104 M</td>
<td>national &amp; international</td>
<td>3.6-6.4-1.5 = endomorphic-mesomorph</td>
<td>Franchini et al. (2014)</td>
<td></td>
</tr>
<tr>
<td>Wrestlers</td>
<td>N/A</td>
<td>70 M</td>
<td>19.8 ± 0.9</td>
<td>elite</td>
<td>N/A = mesomorphy</td>
<td>Mirzaei et al. (2009)</td>
</tr>
<tr>
<td>Boxers &amp; Nonathletes</td>
<td>Heath-Carter</td>
<td>23 M</td>
<td>19.3 ± 0.3</td>
<td>elite</td>
<td>2.3-3.7-2.3</td>
<td>Noh et al., 2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23 M</td>
<td>22.6 ± 0.6</td>
<td>nonathletes</td>
<td>3.0-3.0-2.6</td>
<td></td>
</tr>
<tr>
<td>Wrestlers</td>
<td>Heath-Carter</td>
<td>23 M</td>
<td>24.9 ± 5.5</td>
<td>elite</td>
<td>N/A heavier = endomorphomesomorph lighter = balanced mesomorph</td>
<td>Sterkowicz-Przybycień et al. (2011)</td>
</tr>
<tr>
<td>Kick Boxers</td>
<td>Heath-Carter</td>
<td>4 M</td>
<td>27</td>
<td>elite</td>
<td>2.6-4.3-2.5 = mesomedial body types</td>
<td>Zabukovec &amp; Tiidus (1995)</td>
</tr>
<tr>
<td>MMA</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Body composition in MMA athletes

Body composition measures can be used to estimate an individual’s optimum nutritional needs and body weight (Heyward, 2010). It may also be used to estimate a competitive body weight for athletes participating in sports that have weight divisions for competition (e.g., wrestling, boxing, and judo). Relative percent body fat (%BF) is commonly used to classify level of body fatness. Reported mean values for %BF found across age groups for male MMA athletes are shown in Table 2 along with classifications relative to healthy adults (ACSM, 2014) (Alm & Yu, 2013; Braswell et al., 2010; Gochioco et al., 2010; Gochioco et al., 2011; Schick, et al., 2010; Siqueido, 2010).
Table 2. Body Composition in MMA Athletes

<table>
<thead>
<tr>
<th>TESTS</th>
<th>PROTOCOL</th>
<th>N = LEVEL</th>
<th>AGE</th>
<th>RESULTS (* &amp; classification)</th>
<th>SOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEXA</td>
<td>11 (level N/A)</td>
<td>26.5 ± 4.7</td>
<td>12.3 ± 5.8 % (67*= G)</td>
<td>Siqueido (2010)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 PRO</td>
<td>29.6 ± 5.5</td>
<td>1st: 12.3 ± 0.5 %</td>
<td>Alm and Yu (2013)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2nd: 14.2 ± 1.9 % (60-70*= G)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skinfold</td>
<td>7 sites (Jackson &amp; Pollock)</td>
<td>11 amateur</td>
<td>25.5 ± 5.7</td>
<td>11.7 ± 4.0 % (77*= G)</td>
<td>Schick et al. (2010)</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>8 amateur</td>
<td>26.9 ± 6.1</td>
<td>13.3 ± 4.2 % (65*= G)</td>
<td>Gochioco et al. (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 amateur</td>
<td>25.6 ± 5.8</td>
<td>11.8 ± 4.1 % (77*= G)</td>
<td>Gochioco et al. (2011)</td>
</tr>
<tr>
<td>BIA</td>
<td>N/A</td>
<td>18-36</td>
<td>MMA sig. leaner than TMA, did not report #</td>
<td>Braswell et al. (2010)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GRP:1 (n=6) PRO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&amp; amateur MMA;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GRP:2 (n=6) TMA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: DEXA = dual energy x-ray absorptiometry; % = percent body fat; *percentile rank; G = good; N/A = not available; BIA = bioelectrical impedance analysis; GRP = group; PRO = professional; ABV = above; AVG = average; n = sample; sig. = significance; dif. = difference; MMA = mixed martial artist; TMA = traditional martial artist*
Siqueido (2010) found MMA fighters with an average age of 26.5 ± 6.1 years to have %BF value of around 12.3 ± 5.8. Cooper Institute (2009) rates 12.5 %BF in the 67 percentile, which is classified as good. Schick et al. (2010) reported MMA athletes with an average age of 25.5 ± 5.7 years to have a mean %BF of 11.7 ± 4.0, which is rated in the 77 percentile and classified as good when using age (Cooper Institute, 2009). Alm and Yu (2013) tested MMA subjects twice on two separate occasions with one year apart. Alm and Yu (2013) found MMA athletes around ages 29.6 ± 5.5 years to have a mean %BF of 12.3 ± 0.54 in their pre-test and 14.2 ± 1.9 in the post-test, which are both ranked in the 60-70 percentile and are classified as good (Cooper Institute, 2009). Gochioco et al. (2010) reported a mean value of 13.3 ± 4.2 %BF in MMA fighters ages 26.9 ± 6.1 years, which is ranked in the 65 percentile and is classified as good. Another study by Gochioco et al. (2011) reported a mean value of 11.8 ± 4.1 %BF for fighters around ages 25.6 ± 5.8 years, which is ranked in the 77 percentile and classified as good. Braswell et al. (2010) noted MMA fighters, ages 18-36 years to be significantly leaner than traditional martial artists.

The %BF level will vary depending on the weight class of an MMA athlete, and generally the heavier the fighter the more body fat they will have (Siqueido, 2010). In comparison to other combat sport athletes, judo athletes had 11.4 %BF, wrestlers 7.6-11.8 %BF, and kung fu athletes had 9.5 %BF. MMA athletes therefore had similar %BF to judokas, but greater than wrestlers and kung fu athletes (Schick et al., 2010 & Gochioco et al., 2010). Greater levels of %BF of MMA athletes compared to wrestlers and kung fu athletes may be due to a less restrictive diet and because MMA subjects in
the aforementioned studies did not compete at a national level or team, which would afford them less training sessions per day (Schick et al., 2010).

Within current available literature on MMA fighters, results show that %BF values for MMA athletes ranged from 11.8 to 14.2 %BF (60 – 77 percentile), which are within the range of good (Cooper Institute, 2009). Due to the infancy of science investigating MMA it is difficult to assess whether having a %BF classified as good to be beneficial or not for optimal performance in a competition. However, as is established in the scientific literature the addition of resistance training and cardiovascular exercise are proven to be highly effective in altering body weight and composition (Heyward, 2010). Ratamess (2012) states that an increase in lean muscle may enable MMA athletes to generate more force in a short period of time, contributing to agility, quickness, and speed performance. Since MMA is a weight class sport, it may be recommended that improving strength and power while maintaining normal weight but increasing lean muscle may be of great value.

Cardiorespiratory endurance in MMA athletes

Cardiorespiratory endurance is the ability to sustain extended exercise that combines both the heart and lungs (Heyward, 2010). According to Impellizzeri and Marcora (2007), “Maximum Oxygen Uptake (VO2max) is a valid indicator of the functions of breathing, heart, lungs, and the muscular systems that work synergistically”. Reported values of VO2max are seen across age groups of MMA athletes in Table 3 along with classifications relative to healthy adults (ACSM, 2014) (Alm & Yu, 2013;
Braswell et al., 2010; Gochioco, et al., 2010; Gochioco, et al., 2011; Schick, et al., 2010; Siqueido, 2010; Tota et al., 2014).
Table 3. Cardiorespiratory Endurance in MMA Athletes measured by VO2max

<table>
<thead>
<tr>
<th>PROTOCOL</th>
<th>N = LEVEL</th>
<th>AGE</th>
<th>RESULTS (* &amp; classification)</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruce (1973), GXT, TM</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>55.4 ± 6.6 ml/kg/min (95*/= SUP)</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td>Gerkin, TM</td>
<td>11 amateur</td>
<td>25.5 ± 5.7</td>
<td>55.5 ± 7.3 ml/kg/min (95*/= SUP)</td>
<td>Schick et al. (2010)</td>
</tr>
<tr>
<td>Speed on TM increased to 7km/h,9km/h,10.6km/h,12km/h every 3 min till</td>
<td>5 PRO</td>
<td>29.6 ± 5.5</td>
<td>1st: 62.8 ± 4.9; 2nd: 60.5 ± 5.1 ml/kg/min (&gt;99*/=&gt;SUP)</td>
<td>Alm and Yu (2013)</td>
</tr>
<tr>
<td>exhausted, TM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>8 amateur</td>
<td>26.9 ± 6.1</td>
<td>53.4 ± 5.8 ml/kg/min (87*/= EXC)</td>
<td>Gochioco et al. (2010)</td>
</tr>
<tr>
<td>Gerkin</td>
<td>11 amateur</td>
<td>25.6 ± 5.8</td>
<td>55.5 ± 7.4 ml/kg/min (95*/= SUP)</td>
<td>Gochioco et al. (2011)</td>
</tr>
<tr>
<td>Speed on TM began 8km/h &amp; increased 1km/h every 2 min until failure</td>
<td>1 PRO</td>
<td>N/A</td>
<td>PRT: 57.1</td>
<td>Tota et al. (2014)</td>
</tr>
<tr>
<td>GRP:1(n=6) PRO &amp; amateur; GRP:2(n=6) TMA;</td>
<td></td>
<td></td>
<td>POT: 58.4 ml/kg/min (97*/= SUP)</td>
<td></td>
</tr>
</tbody>
</table>

*percentile rank; G = good; N/A = not available; GRP = group; PRO = professional; ABV = above; AVG = average; sig. = significance; dif. = difference; SUP = superior; > = greater than; EXC = excellent; MMA = mixed martial artist; TMA = traditional martial artist; VO2max = maximal oxygen uptake; GXT = graded exercise test; TM = treadmill; PRT = pre-training; POT = post-training
Three studies on MMA fighters reported similar VO2max mean values of 55.4 ± 6.6 ml/kg/min, 55.5 ± 7.3 ml/kg/min, and 55.5 ± 7.4 ml/kg/min (Siqueido, 2010; Schick et al., 2010; Gochioco et al., 2011). These three studies show an average value of VO2max for MMA athletes to be ranked in the 95 percentile, which is classified as superior according to Cooper Institute (2009) norms when using age and sex. Alm and Yu (2013) found MMA athletes ages 29.6 ± 5.5 years to have a mean VO2max of 62.8 ± 4.9 ml/kg/min in their pre-test and 60.5 ± 5.1 ml/kg/min in their post-test, which are both above the 99 percentile and classified above superior (Cooper Institute, 2009). Gochioco et al. (2010) reported MMA fighters around 26.9 ± 6.1 years of age to have a VO2max averaged 53.4 ± 5.8 ml/kg/min, which is ranked in the 87 percentile and classified as excellent (Cooper Institute, 2009). Braswell et al. (2010) reported amateur and professional MMA fighters between ages 18-36 years did not have significantly different VO2max values between each other. However, Braswell et al. (2010) did not report an exact value, but did note a trend of a higher aerobic capacity in the professional and amateur MMA athletes compared to the traditional martial artist in the study (Braswell et al., 2010).

Tota et al. (2014) did a case study on one professional MMA athlete (age not reported) and found VO2max of 57.1 ml/kg/min for pre-test and 58.4 ml/kg/min in the post-test, which is ranked in the 97 percentile, classified as superior (Cooper Institute, 2009). In comparison to other combat sports, Schick et al. (2010) reported judo athletes VO2max mean was 48.3 ± 8.1 ml/kg/min, wrestlers were 54.6 ± 2.0, and kickboxers was 62.7 ± 3.6. Gochioco et al. (2010) reported judo athletes to be 58.1 ± 10.8 ml/kg/min and
wrestlers to be 53.91 ± 1.70 ml/kg/min. Crisafulli et al. (2009) found muy thai kickboxers had mean VO2max of 48.5 ml/kg/min. Judging by these previous studies, VO2max in combat sports heavily incorporated in MMA range between the low 75% and above the high 99% according to Cooper Institute standards. MMA athlete VO2max values are greater than judokas, comparable to wrestlers, and less than boxers and kickboxers. Boxers and kickboxers have 30 – 36 minutes of fight duration in comparison to MMA 15 – 25 minutes, which places greater emphasis on aerobic training in boxing and kickboxing compared to judo, wrestling, and MMA.

The current available literature on MMA fighters suggests that VO2max values range from 87th to above the 99th percentile rankings when compared to norms (Cooper Institute), classified at or above superior for their age (Cooper Institute, 2009). If a bout ends in the judges’ decision, the duration of the fight will range from 9 – 15 (amateur bout) or 15 – 25 minutes (professional bouts) depending on if it is a championship bout. It is known that after 3 minutes of high intensity activity the aerobic system is dominant (Gillis, 2013). Because MMA competitions consist of short breaks (1 minute) between bouts, it could be argued that the aerobic energy system predominates, especially during later rounds. This suggests that MMA athletes may require a high VO2max, similar to their judo and wrestling peers because an MMA match has more potential for fight duration. However, MMA athletes also participate in both boxing and kickboxing which have more potential for fight duration than the grappling components, therefore a weak aerobic system may be a limiting factor in training or competition performance (Schick et
This suggests that MMA fighters should develop high aerobic capacity to perform consistently at high levels throughout the bout. Having a high VO2max in MMA is of extreme importance because the sport is consistent with subsequent high and low intensity periods (Alm & Yu, 2013; Amtmann, 2008; Lenetsky & Harris, 2012). High intensity periods include explosive takedown or striking combination which is aided by anaerobic system (Lenetsky & Harris, 2012; Bounty et al., 2011; Tack, 2013). Low intensity periods include athletes moving around circling each other, which in essence is active recovery and is aided by the aerobic system. Alm and Yu (2013) suggest that energy supply of MMA fighters may be similar to that in repeated sprinting; estimates are that anaerobic systems contribute 40% of the energy at the first sprint and drop to 9% after a repetition of 10 sprints. In addition, the aerobic system contributes less than 10% of the energy at the first sprint but accounts for over 40% of the energy needed at the last sprint; thus even though a well-developed anaerobic system is very important in MMA, having a higher aerobic capacity prevents premature fatigue and grants an ability to sustain a higher intensity during training or a bout (Siqueido, 2010; Schick et al., 2010; Alm & Yu, 2013).

**Muscular strength in MMA athletes**

In addition to cardiovascular exercise, resistance training is proven to be highly effective in altering body weight and composition, which may be useful for MMA athletes that are in and below the good ranges for % BF (Heyward, 2010). Strength is highly recognized as one of the most important fundamental characteristics in health and
sport performance (Moir, 2012). Muscular strength is the capability of muscles to generate maximal contractile forces against resistance in a single contraction (Heyward, 2010). One of most common ways to determine strength is to determine how much an individual can lift in a one repetition maximum (1RM) (Brzycki, 1993). Heyward (2010) recommends the bench press and leg press for assessing upper and lower body strength. To determine relative strength, the amount lifted is divided (i) by the body mass (BM) of the lifter. Reported values of muscular strength for upper and lower-body for MMA athletes are found in Table 4 (Alm & Yu, 2013; Gochioco, et al. 2010; Gochioco, et al., 2011; Schick, et al., 2010; Siqueido, 2010).
Table 4. Muscular Strength in MMA Athletes

<table>
<thead>
<tr>
<th>TEST</th>
<th>PROTOCOL</th>
<th>N=LEVEL</th>
<th>AGE</th>
<th>RESULTS (* &amp; classification)</th>
<th>SOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Press</td>
<td>1RM</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>1RM: 86.0 ± 17.8 kg</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 amateur</td>
<td>25.5 ± 5.7</td>
<td>1.2 ± 0.1a (75*= ABV. AVG)</td>
<td>Schick et al. (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 amateur</td>
<td>26.9 ± 6.1</td>
<td>1.3 ± 0.1a (75*= ABV. AVG)</td>
<td>Gochioco et al. (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 amateur</td>
<td>25.6 ± 5.8</td>
<td>1.3 ± 0.2a (75*= ABV. AVG)</td>
<td>Gochioco et al. (2011)</td>
</tr>
<tr>
<td>Back Squat</td>
<td>1RM</td>
<td>11 amateur</td>
<td>25.5 ± 5.7</td>
<td>1.4 ± 0.1a (N/A)</td>
<td>Schick et al. (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 amateur</td>
<td>26.9 ± 6.1</td>
<td>1.5 ± 0.2a (N/A)</td>
<td>Gochioco et al. (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 amateur</td>
<td>25.6 ± 5.8</td>
<td>1.5 ± 0.2a (N/A)</td>
<td>Gochioco et al. (2011)</td>
</tr>
<tr>
<td>Isometric Grip</td>
<td>MVC</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>R: 52.1 ± 8.3; L: 47.8 ± 7.8 kg (AVG)</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 amateur</td>
<td>25.5 ± 5.7</td>
<td>R: 45.8 ± 6.2 kg; L: 45.6 ± 5.9 kg (BLW. AVG &amp; AVG)</td>
<td>Schick et al. (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N/A</td>
<td>26.9 ± 6.1</td>
<td>91.5 ± 6.5 kg (G)</td>
<td>Gochioco et al. (2010)</td>
</tr>
<tr>
<td>Leg Press</td>
<td>1RM</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>1RM: 321.7 ± 41.8 kg</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td>Seated Row</td>
<td>1RM</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>1RM: 80.5 ± 11.9 kg</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td>Deadlift</td>
<td>N/A</td>
<td>5 PRO</td>
<td>29.6 ± 5.5</td>
<td>1st: 2.2 ± 0.19a (N/A); 2nd: 2.1 ± 0.3a (N/A)</td>
<td>Alm and Yu (2013)</td>
</tr>
<tr>
<td>Hang Clean</td>
<td>1RM</td>
<td>5 PRO</td>
<td>29.6 ± 5.5</td>
<td>1st: 1.1 ± 0.1a (N/A); 2nd: 1.1 ± 0.1a (N/A)</td>
<td>Alm and Yu (2013)</td>
</tr>
</tbody>
</table>

Note. *percentile rank; one repetition maximum with press weight ratio = weight pushed in kilograms per body weight in kilograms; G = good; N/A = not available; GRP = group; PRO = professional; ABV = above; AVG = average; n = sample; sig. = significance; dif. = difference; SUP = superior; > = greater than; EXC = excellent; MMA = mixed martial artist; TMA = traditional martial artist; 1RM = one repetition maximum; MVC = maximal voluntary contraction; R = right; L = left; BLW = below; PRT = pre-training; POT = post-training
Siqueido (2010) found MMA athletes with a mean weight of 80.3 ± 7.1 kg had an average 1RM bench press of 86.0 ± 17.8 kg. There are no norms for 1RM on the bench press, only 1RM/BM ratio norms. Three groups of researchers reported 1-RM/BM for bench press to have mean values of 1.2 ± 0.1 (Schick et al., 2010), 1.3 ± 0.1 (Gochioco et al., 2010), and 1.3 ± 0.2 (Gochioco et al., 2011), which are ranked in the 75 percentile and classified above average (Cooper Institute, 2009). The same researchers also assessed 1RM/BM using bilateral back squat reporting means: 1.4 ± 0.1 (Schick et al., 2010), 1.5 ± 0.2 (Gochioco et al., 2010), 1.5 ± 0.2 (Gochioco et al., 2011), which have no 1RM/BM rankings. Siqueido (2010) reported an average 1RM leg press value of 321.7 ± 41.8 kg. There are no norms for 1RM leg press. Siqueido (2010) also measured back strength using seated row and reported a mean 1RM value of 80.5 ± 11.9 kg and subjects had a body mass of 80.3 ± 7.1 kg. There are no norm values for the seated row.

Alm and Yu (2013) reported a mean value in deadlift: pre-test 2.2 ± 0.2 and post-test 2.1 ± 0.3. Alm and Yu (2013) also reported a mean hang cleans 1.1 ± 0.1 in their pre-test and 1.1 ± 0.1 in the post-test. There are no 1RM/BM norm values for squats, deadlifts, and hang cleans as well as no 1RM norms for the bench and leg press, therefore we cannot compare strength levels to other groups. In comparison to other combat sports, Schick et al. (2010) reported judo athletes 1.2, Gochioco et al. (2010) noted judo athletes to be 1.2, and wrestlers to be 1.5. With regard to upper body strength, wrestlers possess a greater level of strength than MMA fighters. However, the strength values in MMA athletes are very similar to judokas. 1RM/BM assessed by the bilateral back squat of judo
and wrestlers was noted 1.4, which are comparable to MMA athletes (Gochioco et al., 2010; Gochioco et al., 2011; Schick et al., 2010).

Current scientific literature on MMA athletes shows average 1RM/BM bench press to be ranked at the 75th percentile compared to general population norms (Cooper Institute, 2009). This means that upper body strength for MMA fighters are classified above average. However, there are no norm values for bilateral back squat, seated row, and deadlift, which make it impossible to classify overall upper and lower body strength for MMA athletes at this time.

Franchini et al. (2007) states that strength is important for injury prevention, because it not only strengthens the muscles but the bones, joints, and ligaments as well. According to Amtmann et al. (2003) strength training mutually improves performance and decreases the probability of injury. Strengthening of the muscles surrounding a joint augments structural integrity of the joint and increased muscle mass aids in the frequent falls and repetitive forces from striking and takedowns these athletes endure on a regular basis (Amtmann & Berry, 2003). As is conveyed in the literature in combat sports, fractures of bones and dislocations of joints and strains of ligament injuries are very common (Franchini et al., 2007; Amtmann & Berry, 2003).

James et al. (2013) explains that strength is extremely important for MMA fighters primarily for the wrestling and grappling portions, for takedown, submitting, or controlling opponent. Franchini et al. (2007) noted that over 50% of MMA bouts end on the ground. Thus, improvement in strength for MMA athletes may contribute to performance enhancement of a decisive MMA skill (James et al., 2013). In addition,
Schmidtbleicher (1992) states that maximum strength is the foundation on which power is developed: the stronger an athlete becomes, the more potential they have to generate more power. This is because in essence, power is strength but with speed. Chris Tack (2013) asserts that maximal strength and its underlying neuromuscular characteristics play a pivotal role in the production of force and athletic performance. Therefore, MMA fighters may benefit greatly by having high strength to mass ratio while maintaining their normal weight class, so they may possess superior athleticism and decrease likelihood of injury (Ratamess, 2012).

Isometric grip strength is measured as the maximum force exerted in a single contraction against an immovable object (Heyward, 2010). Siqueido (2010) reported average 1RM grip strength for the right hand (RH) 52.1 ± 8.3kg, and the left hand (LH) 47.8 ± 7.8kg in MMA athletes. 1RM grip strength general population norm values from Corbin & Colleagues (1978) classify a RH mean value of 52.1 kg as average and LH mean of 47.8 kg, as average as well. Schick, et al. (2010) found mean values for the RH to be 45.8 ± 6.2 kg and LH 45.6 ± 5.9 kg in MMA athletes, which are classified as below average and average (Corbin & Colleagues, 1978). Gochioco et al. (2010) reported average combined grip strength of 91.5 ± 6.5 kg for MMA athletes which, is classified as good from general population norms (Canadian Society for Exercise Physiology, 2010). In comparison to other combat sports that are heavily incorporated into MMA, Schick et al. (2010) reported boxers to be 58.2 kg and Gochioco et al. (2010) reported wrestlers to 86.2 kg, which place both in excellent rankings and higher than MMA athletes (Canadian
Society for Exercise Physiology, 2010). Boxing and wrestling’s greater grip strength may be due to their emphasis on upper body development and training methods.

Current literature on MMA fighters show that the right and left hand grip strength are classified between below average and average, but combined grip strength is classified as good (Corbin & Colleagues, 1978). Thus, improving isometric grip strength in MMA athletes may be advantageous in training or competition; especially during grappling portions, as Franchini et al. (2007) stated that 50% of MMA bouts end on the ground, aiding in squeezing and pulling motions for takedown, submissions, or tie-up controlling or defending an opponent.

Muscular endurance in MMA athletes

Muscular endurance is the ability of a muscle or muscle groups to exert submaximal force for extended periods (Heyward, 2010). The Canadian Society for Exercise Physiology (2010) recommends using push up-test and sit-up test to assess upper body and abdominal muscular endurance. Siqueido (2010) assessed MMA fighters with an average age of 26.5 ± 6.1 years and measured muscular endurance with push-up test, reporting a mean value of 37.6 push-ups, which is classified above excellent compared to general population norms (Canadian Society for Exercise Physiology, 2010). Muscular endurance, measured with a sit-up test, was also assessed and reported to average 48.6 push-ups, which is also above excellent classifications (Canadian Society for Exercise Physiology, 2010).
Available literature on MMA athletes show that muscular endurance values for MMA athletes are above excellent ranges when compared to general population norms. Muscular endurance is pertinent for MMA athletes because the sport involves a lot of continuous movements, like prolonged striking combinations or submission attempts and defenses that are heavily influenced by the endurance capacity of the muscles. Reported values for muscular endurance of MMA athletes can be found in Table 5 (Gochioco, et al., 2010; Gochioco, et al., 2011; Schick, et al., 2010; Siqueido 2010).

**Flexibility in MMA athletes**

Flexibility is the ability of a joint to move through a full range of motion (Heyward, 2010). Common measurements for flexibility include sit and reach test to assess trunk flexion and goniometer to assess shoulder flexion. Flexibility is also important due to the stresses placed on the joints of the shoulders and hips. Flexibility also may help an athlete to be able to properly positioned to finish a submission or defend a submission against an opponent. Reported values for flexibility of MMA athletes can be found in Table 5 (Gochioco, et al., 2010; Gochioco, et al., 2011; Schick, et al., 2010; Siqueido, 2010. Siqueido (2010) used the modified sit and reach test and found MMA fighters to have an average value of 36.4 cm ± 8.2 cm (14 inches). Normative data of healthy adults from Haeger (1989) rank 14.4 inches in the 50th percentile.
Table 5. Muscular Endurance and Flexibility in MMA Athletes

<table>
<thead>
<tr>
<th>TESTS</th>
<th>PROTOCOL</th>
<th>LEVEL</th>
<th>AGE</th>
<th>RESULTS (* &amp; classification)</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push-up test</td>
<td>80b/min CSEP</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>37.6 ± 6.8 b/min (&gt; EXC)</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td>Sit-up test</td>
<td>50b/min CSEP</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>48.6 ± 5.3 b/min (&gt; EXC)</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td>Sit &amp; Reach</td>
<td>Modified Sit &amp; Reach</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>36.4 ± 8.2 cm (50*)</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td></td>
<td>Sit &amp; Reach</td>
<td>11 amateur</td>
<td>25.5 ± 5.7</td>
<td>30.3 ± 10.6 cm (G)</td>
<td>Schick, et al. (2010)</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>8 amateur</td>
<td>26.9 ± 6.1</td>
<td>29.9 ± 9.0 cm (fair)</td>
<td>Gochioco et al. (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 amateur</td>
<td>25.6 ± 5.8</td>
<td>30.3 ± 10.7 cm (G)</td>
<td>Gochioco et al. (2011)</td>
</tr>
<tr>
<td>Goniometer</td>
<td>Shoulder Flexion</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>R-169.2 ± 5.3 DEG</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td></td>
<td>(R/L)</td>
<td></td>
<td></td>
<td>L-169.8 ± 4.6 DEG (AVG-ROM)</td>
<td></td>
</tr>
</tbody>
</table>

*percentile rank; G = good; N/A = not available; GRP = group; PRO = professional; ABV = above; AVG = average; n = sample; sig. = significance; dif. = difference; SUP = superior; > = greater than; EXC = excellent; MMA = mixed martial artist; TMA = traditional martial artist; R = right; L = left; BLW = below; CSEP = canadian society for exercise physiology; DEG = degrees; ROM = range of motion; PRT = pre-training; POT = post-training
Three groups of researchers used the standard sit and reach test and reported average values of: 30.3 ± 10.6 cm (Schick, et al., 2010), 29.9 ± 9.0 cm (Gochioco et al., 2010), and 30.3 ± 10.7 cm (Gochioco et al., 2011) in the MMA fighters. The Canadian Physical Activity, Fitness and Lifestyle Approach (2003) classifies 29 cm as fair and 30 cm as good in healthy adults. Siqueido (2010) measured shoulder flexion and reported mean values of 169.2 ± 5.3 degrees for the right hand and 169.8 ± 4.6 degrees. Data from the American Academy of Orthopedic Surgeons (1994) and the American Medical Associations (1988) rank 169 degrees within the average range of motion (ROM) for healthy adults. In comparison to other combat sports, Schick, et al. (2010) reported that wrestlers had a similar sit and reach value of 30 cm, however, Gochioco et al. (2010) reported that kung fu athletes had a much higher value of 45.5 cm. MMA and wrestling are not known to focus on flexibility training to the same degree as kung fu and tai kwon do athletes, which may be the reason MMA athletes possess less flexibility (Schick et al., 2010).

Within current literature, MMA fighters appear to have between just fair and good flexibility. This poor ranking of MMA athletes is inferior to Hopkins and Hoeger (1992) reported mean of 32.5 ± 8.6 cm in modified sit and reach test for untrained males. It may be important for MMA athletes to increase their flexibility because it is a contributing factor to performance in grappling and striking portions of a bout, and possibly because it may be a good injury deterrent (Siqueido, 2010).

Skill-related Fitness Components of MMA Athletes
Muscular power in MMA athletes

Muscular power is related to the ability of muscle to exert a high force while contracting at a high speed (Peterson, 2012). Baechle and Earle (2008) assert that the term power is “widely used to describe some important abilities that contribute to maximal human efforts in sport and other physical activities”. Common measures to assess power include 1RM power cleans, snatch, and push jerks, as well as the standing vertical jump. The transfer of force through the transverse plane is important for striking (Tack, C., 2013). Reported values for power of MMA fighters are found in Table 6 (Alm & Yu, 2013; Gochioco, et al., 2010; Gochioco, et al., 2011; Schick, et al., 2010; Siqueido, 2010).

To assess muscular leg power in MMA athletes, Siqueido (2010) measured the standing vertical jump (SVJ) and reported a value around 60.6 ± 5.5 cm for the right arm jump height and 58.0 ± 6.9 cm for the left hand jump height. There are no norms data on the SVJ, but descriptive data by Hoffman (2006) noted that there is a value of 61.0 cm in male recreational college athletes. The descriptive data for MMA athletes (Siqueido, 2010) appears similar to recreational college athletes (Hoffman, 2006). Schick, et al. (2010) found a mean 57.6 ± 7.3 cm, which is less than recreational college athletes (Hoffman, 2006). Alm and Yu (2013) reported a mean value of 50.2 ± 5.6 cm for the pre-test and 47.2 ± 1.6 cm in the post-test, which are both lower than recreational college athletes (Hoffman, 2006).

Gochioco et al. (2010) reported an average value of 58.42 ± 5.84 cm in the SVJ, which is less than recreational college athletes (Hoffman, 2006). Another study by
Gochioco et al. (2011) reported a mean value of 57.61 ± 7.30 cm, which is less than recreational college athletes (Hoffman, 2006). In comparison, to other combat sports, Schick, et al. (2010) noted that wrestlers had a mean value of 60cm, which is greater than MMA athletes in studies Schick, et al. (2010) Alm & Yu (2013), Gochioco et al. (2010), and Gochioco et al. (2011), but similar to Siqueido (2010) study. Slight differences in wrestlers compared to MMA athletes may be due to their greater anaerobic demand in wrestling and the fact that the wrestlers reported were on a national team (Schick et al., 2010).

Within current literature, MMA fighters on average appear to have less power than male recreational college athletes. Increasing power in MMA athletes may be pertinent, because power is essential for escaping from dangerous positions, and executing successful striking combinations and takedowns. The athlete that is more powerful has a higher probability of ending the fight, especially early in the rounds, thus ideally power as well as power endurance is important in MMA (Bounty et al., 2011; James et al., 2013; Tack, 2013).

Agility in MMA athletes

Agility is defined as the ability to start, stop, or change the direction of the body in a rapid way. Reported values for agility of MMA athletes are found in Table 6 (Siqueido, 2010). There was only one study that reported on agility in MMA athletes (using the T-Test). Siqueido (2010) reported a mean value of 10.3 ± 0.6 seconds. There are no normative data for the T-test relevant to MMA or subcomponent sports; however,
MMA athletes mean score of 10.3 seconds was higher than that for recreational college athletes (Hoffman, 2006). Agility may help MMA fighters to quickly maneuver and change positions/stances. This allows the athlete to evade an attack or launch a strike at undefended area (i.e., moving laterally in order to avoid an opponent's blow and thus being able to quickly launch an effective counter attack against an off-balance opponent; Tack, 2013).
Table 6. Power and Agility in MMA Athletes

<table>
<thead>
<tr>
<th>TESTS</th>
<th>PROTOCOL</th>
<th>LEVEL</th>
<th>AGE</th>
<th>RESULTS (* &amp; classification)</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Jump</td>
<td>Standing</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>R: AJH: 60.6 ± 5.5 cm</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 amateur</td>
<td>25.5 ± 5.7</td>
<td>L: AJH: 58.0 ± 6.9 cm (N/A)</td>
<td>Schick, et al. (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 PRO</td>
<td>29.6 ± 5.5</td>
<td>1st: 50.2 ± 5.6 cm</td>
<td>Alm and Yu (2013)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 amateur</td>
<td>26.9 ± 6.1</td>
<td>2nd: 47.2 ± 1.6 cm (N/A)</td>
<td>Gochioco et al. (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 amateur</td>
<td>25.6 ± 6.8</td>
<td>58.4 ± 5.8 cm (N/A)</td>
<td>Gochioco et al. (2011)</td>
</tr>
<tr>
<td>Squat Jump</td>
<td>Static-squat</td>
<td>5 PRO</td>
<td>29.6 ± 5.5</td>
<td>1st: 40.3 ± 3.8 cm</td>
<td>Alm and Yu (2013)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2nd: 36.2 ± 3.6 cm (N/A)</td>
<td></td>
</tr>
<tr>
<td>T-Test</td>
<td>Miller et al. (2006) Brower timing system</td>
<td>11 N/A</td>
<td>26.5 ± 4.7</td>
<td>10.3 ± 0.6 seconds</td>
<td>Siqueido (2010)</td>
</tr>
</tbody>
</table>

*percentile rank; G = good; N/A = not available; MMA = mixed martial artist; TMA = traditional martial artist; R = right; L = left; AJH = arm jump height; MP = mean power; PP = peak power; PRT = pre-training; POT = post-training
Anaerobic capacity (ergometer) in MMA athletes

The Wingate muscular power test is an anaerobic ergometer test that can measure peak anaerobic power, anaerobic capacity, and power decrement (Peterson, 2012). Power is expressed in total Watts (W), or relative to body mass (W/kg). A case study by Tota et al. (2014) noted one professional MMA fighter had a mean anaerobic power on the Wingate test performed on the upper limbs of 7.8 W•kg in the first test, and 8.1 W•kg in the second sequence of tests. According to researchers 7.8 W•kg is ranked to be around the 66 – 69% in physically active males and 8.1 W•kg is ranked in the 85% (American Alliance of Health, 1989). However, because the reported value is from a case study done on only one subject, we cannot generalize as to anaerobic power levels in MMA athletes.

Conclusion

Literature has conveyed that MMA fighters %BF to be in the range of good, strength to be in the ranges fair to good in comparison to general population norms, and both of these components have a correlation to power (Peterson, 2012). As previous mentioned, Schmidtbleicher (1992) noted that maximum strength is the foundation on which power is developed, and Peterson (2012) emphasizes that an increase in lean muscle may enable MMA athletes to generate more force in a short period of time, contributing to agility, quickness, and speed performance. Because MMA is a weight class sport, improving strength and power while maintaining normal weight but
increasing lean muscle may be of extreme importance for optimal performance in MMA athletes.

Need for Research on MMA Athletes and the Limitations of Other Studies

Based on the available literature, much work is needed to construct a complete physical and physiological profile of elite and amateur MMA athletes. Shared reported data from other combat sports that are considered large components in MMA may transfer a lot or a little to none, but that is almost impossible to tell. The eight studies performed on MMA fighters were adequate benchmarks for the future of the sport and a scientific start in the profiling of these unique athletes. Moreover, three out of the eight studies were abstracts (Braswell et al., 2010; Schick et al., 2010; Tota et al., 2014); three out of the eight used data from the same study but wrote separate papers comparing MMA athletes to other combat sports and other to mainstream sports (Gochioco et al., 2010; Gochioco et al., 2011; Schick et al., 2010). Three out of the eight studies researched professional MMA fighters; however, one was a case study that only had one subject (Tota et al., 2014). Whereas, another study had five subjects who were tested twice with one year apart (Alm and Yu, 2013) and the other had six subjects, but listed them as a mix of both professional and amateur (Braswell et al., 2010).

There was only one study that had a complete health-related physical fitness tests, but the study did not disclose the MMA athletes level of competition and began with 16 subjects and ended with 11 (Siqueido, 2010). In summary, group of researchers
investigated the health-related physical fitness test components in MMA athletes. Table 7 illustrates the absence of information on MMA athletes in this point in time, specifically the skill-related physical fitness components.
Table 7. Skill-related Physical Fitness Components in MMA Athletes

<table>
<thead>
<tr>
<th>SKILL COMPONENTS</th>
<th>TESTS</th>
<th>PROTOCOL</th>
<th>LEVEL</th>
<th>RESULTS</th>
<th>SOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agility</td>
<td>Av</td>
<td>Av</td>
<td>Av</td>
<td>Av</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td>Power</td>
<td>Av</td>
<td>Av</td>
<td>Av</td>
<td>Av</td>
<td>Siqueido (2010)</td>
</tr>
<tr>
<td>Speed</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Balance</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Coordination</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Note. Av = available; N/A = not available.*
Statement of Problem

In the available but trivial scientific research on MMA athletes, there are a few researchers that investigated and reported the health-related physical fitness test components (i.e., body composition, cardiorespiratory endurance, strength, endurance, and flexibility), in MMA athletes. However, to the best of our knowledge, no researcher has investigated completely all the skill-related physical fitness components (i.e., agility, power, speed, balance, coordination, reaction time) (only power and agility) or assessed somatotyping (measuring body shape and size) in MMA athletes. To the best of our knowledge, research on somatotyping and skill-related fitness performance testing on elite and amateur MMA fighter is nonexistent.

Purpose of Study

This project along with previous studies may fill the gaps in the literature, specifically somatotype and skill-related fitness performance testing in MMA athletes. Thus, the primary purpose of the project is to describe the anthropometric and physical characteristics of MMA Fighters to establish a reference for their athletic profile, focusing primarily on:

- Somatotyping
- Skill-related physical fitness test components

Secondly, focusing on:
• Muscular Fitness test

Significance of the Study

This project may help provide some basic descriptive data that potentially can be used by coaches and athletes to determine level of fitness, physical weaknesses, find an appropriate weight class to compete in, develop training goals, and help coaches prescribe exercise.

Limitations

Limited to the following:

• Testing day of week and time of day was not fixed due to availability of the fighters.
• Fighters in fight camp were unable to do maximal test as they were in the process of cutting weight.
• Some fighters chose not to do certain physical test due to comfort or fear of possible injury.

Delimitations

Delimited to the following:

• Only male athletes were recruited
• All subjects were male and between the ages of 18 to 46 years of age.

• Inclusion criteria included at least 2 years of training or competitive experience as an amateur or professional MMA fighter.

Assumptions

It was assumed that:

• Athlete’s participation outside of the training would not greatly affect the series of measured test.

• Athlete’s followed specific guidelines given to them, e.g., we assume they refrained from CNS stimulating supplementation such as coffee and tea during test days.

• Athlete’s performed to their very best for any and all testing.

• The work/rest protocol allowed sufficient time for athlete to recover from each test and complete series of the battery of field test.

• The athletes were honest on health history and physical activity level questionnaire, pretest conditions, subject screening, and information sheets.
METHODS

Experimental Approach to the Problem

The purpose of the study was to describe the anthropometric and physical characteristics of MMA fighters to establish a reference for their athletic profile. Each subject was required to participate in two separate testing sessions (at least 3 days apart). However, if subject (or coach) felt uncomfortable with any physical testing, they had the choice not to participate in that specific test. To allow adequate recovery time, there was a minimum of three days separating each session. During each session, subjects were asked to participate in a battery of field fitness testing.

Anthropometrics and somatotyping measurements were taken first in the first testing session. Testing included field tests for muscular testing (strength and endurance), balance and steadiness, balance and stability, hand and eye coordination, speed, agility, power, and somatotype (body shape and composition) of MMA Fighters. Prior to beginning of each filed fitness testing session, there was a 10-minute dynamic warm-up series followed by stretching. In between each test there was a 5-minute rest period, with the inclusion on an introduction on the next test. The protocol for this project was approved by Humboldt State University Human Research Review Committee and all subjects will be provided informed and written consent prior to participation.
Timing & order of testing for procedures

Harman (2008) proposed the following order for tests in a battery based on energy system requirements and the skill or coordination demands of the tests: non-fatiguing tests (anthropometric measurements), agility tests, maximum power and strength tests, sprint tests, muscular endurance tests, fatiguing anaerobic tests, aerobic tests. According to Baechle and Earle (2008) following this order should maximize the reliability of each test. Based off the proposed order the sessions were structured as follows:

Session 1: During day one testing, subject’s participated in anthropometric measures including age, height, weight, % body fat (skinfold) and somatotyping. Session one with took approximately 10-15 minutes. Following assessment of anthropometric variables and somatotype, the subject was tested on balance and steadiness (BESS test), agility (hexagon test), and muscular strength (squat, bench, weighted chin up, hand grip). Session 1 took approximately 2 hours to complete.

Session 2: During the second day of testing (at least 3 days from day 1 testing), subjects participated in hand and eye coordination (modified hand wall toss test), balance and stability (modified bass test), muscular power (standing broad jump and seated medicine ball put), speed (10-yard dash), and muscular endurance (65% of 1RM squat, bench, and supinated pull-up test). Session 2 took approximately 1.5 hours to complete.

Participants
Subjects that participated in this project were 17 elites and 13 amateur male subjects that currently had a minimum 2 years of amateur or professional MMA training or competition experience, and were between the ages of 18 and 46. Athlete participants had at least 2 years of training experience in a variety of martial art disciplines, including: Boxing, Wresting, Jiu Jitsu, Judo, karate, Muay Thai Kickboxing, and Tae kwon do. Exclusion criteria were: subjects were required to have no serious injuries that would negatively affect test assessments, and information was obtained through subject information sheets. Word by mouth was used to recruit subjects from approved gym facilities. All subjects were screened prior to being selected for this study to ensure athletes met basic study criteria, including: age (18-46), gender (male), fight status (had competed in the last 12 months), and had no current serious injuries that would negatively affect test assessments.

When the subjects passed initial screening, they completed a consent form (Appendix A), health medical history and physical activity questionnaire (Appendix B), and were verbally asked by assessor to provide in-depth information on contact information, experience in training and competition, level of competition, and weight class. All subjects on the day of testing, prior to administering field fitness tests completed documents that was used to document information applicable to their general health and physiology (e.g., medications, injuries, exercise limitations, illness, etc.) as outlined by the American College of Sports Medicine (ACSM guidelines, 2010). Subjects were screened for cardiovascular or musculoskeletal disease using medical history questionnaire. All subjects had less than two positive cardiovascular risk factors as
outlined by ACSM (ACSM guidelines, 2010). It is important to note that MMA subjects are athletes thus, they are already medically cleared to compete.

Procedure

All testing took place in the Human performance laboratory (HPL) at Humboldt State University (HSU) or gym facility where the participant trained. Measurements were taken at gyms: Adrenaline Performance Center, Montreal Quebec Canada; Lost Boys Jiu Jitsu and Muay Thai, Humboldt California; and Body Shop Fitness, Lakewood California. When scheduling took place, subjects were asked to refrain from using caffeine and alcohol for 24 hours before each testing and training session.

Anthropometric and somatotype (Session 1)

Using the Heath Carter method 10 anthropometric dimensions were needed to calculate somatotype: stretch stature, body mass, 4 skinfolds (triceps, subscapular, supraspinale, medial calf), 2 bone breadths (bicepscondylar humerus and femur), and 2 limb girths (arm flexed and tensed, calf). Jackson & Pollock- site skinfold caliper test; triceps, subscapular, suprailliac, and medial calf. Three measures of each body was recorded and averaged. The following descriptions are adapted from Carter and Heath (1990). Measurements of subject’s stature (height), body mass body mass (weight), skinfolds (triceps, subscapular, supraspinale, medial calf, bicepscondylar breadth (humerus and femur), and upper arm and calf girth. All skinfolds, breadth, and girth were measured
on the right side of the body. For more reliable values, triplicate measurements were taken and the median value was used. Equipment needed are Stadiometer or height scale and headboard, weighing scale, small sliding caliper, flexible steel or fiberglass tape measure, and skinfold caliper. See Appendix H for procedure protocol.

**Anthropometric body fat percentage**

Skinfold measurements were taken to determine distribution of subcutaneous body fat with a Lange Skinfold Caliper at the abdomen, chest, and thigh (Jackson & Pollock, 1985). The accuracy of predicting percent body fat from skinfolds is approximately 3.5 %, assuming appropriate techniques and equations have been used (Jackson & Pollock, 1985; Evans et al., 2005). Factors that may contribute to measurement error within skinfolds include poor technique and/or an inexperienced evaluator, extremely obese or extremely lean subject, and improperly calibrated caliper (Jackson & Pollock, 1985). Percentage of body fat was determined by using the Evans, E.M., Rowe, D.A., Misic, M.M, Prior, B.M., and Arngrimsson, S.A. (2005) equation; black or white collegiate male athletes (Evans et al., 2005). See Appendix D for procedure protocol.

**Balance error scoring system (BESS) test (assess postural steadiness)**

The BESS test assess postural steadiness, has excellent reliability, is easy to perform, requires minimal specialized equipment, and has a large body of literature supporting it. The BESS test has a high reliability (ICCs = .78 to .96) (Riemann,
Guskiewicz, and Shields, 1999). Subject was assessed on three stances (double-leg support, single leg-support, and tandem) held for twenty seconds on two surfaces (firm floor and foam pad) for six permutations (Riemann, Guskiewicz, and Shields, 1999). Equipment needed are a foam balance pad, specifically an airpex foam pad that is one piece of medium density foam (45cm² x 13cm thick, density 60kg/m³, load deflection 80-90). The BESS test protocol was adapted verbatim from Flanagan, 2012. See Appendix D for procedure protocol.

Hexagon test

This agility test measures footwork and is used in sports in which foot placement in all directions and cutting movements are common (Triplett, 2012). The main goal is to cover the course and change direction as quickly as possible without losing one’s balance (Triplett, 2012). The range of test-retest reliability for the hexagon test is .86 to .95 and ease to set up is moderate requiring minimal resources. The test is best performed indoors or a court where distance can be measured. Equipment needed are tape measure, stop watch cones or tape to indicate course layout, and personnel to time and watch for accuracy of course completion. See Appendix D for procedure protocol.

Standing broad jump (SBJ)

Test is frequently used for measuring lower body explosive performance providing information about vertical and horizontal displacement (Peterson, 2012). Leg drive during punching requires ground reaction forces (GRF) to be developed in the
vertical and horizontal directions, suggesting it may be more appropriate to assess leg power in longitudinal movements (Lenetsky, 2013). To perform test a flat jumping surface is needed, at least 20 feet (6 meters) long, gym floors, rubber tracks, and artificial turf field are recommended. Equipment needed are tape measure or commercial SBJ mats may be used, and a roll of masking tape. See Appendix D for procedure protocol.

**Modified seated medicine ball put (20lb)**

The seated medicine ball put field test is most frequently used to measure upper body power and has been validated numerous times and has proven to be reliable across multiple populations (Clemons, Campbell, & Jeansonne, 2010). The test is easy to set up and administer with the direct specificity of movement to a functional task such as rapid punching of combat athletes (Peterson, 2012). See Appendix D for procedure protocol.

**1RM (or 2-5RM) bench press**

Procedure used to test and assess 1RM of bench press and back squat was by Baechle, Earle, and Wathen (2008). According to Reynolds, Gordon, and Robergs (2006) the most accurate submaximal (3-5RM) equations to predict 1RM for bench press are those by Bryzcki (2000) and O’Connor, Simmons, and O’Shea (1989). Bryzcki equation $1RM = \frac{\text{weight lifted}}{1.0278 - [0.0278 \times \text{No. of repetitions}]}$. The following steps were used as the protocol for 1-RM or 2-5RM testing: Subjects warmed up by completing 5-10 repetitions of a sub-maximal weight: one-minute rest. Subject then was asked to perform single repetition efforts with each single effort and asked to lift slightly more weight; an
estimated warm-up load that allows subject to complete 3-5 repetitions by adding 10-20 pounds (4.5-9kg), or 5-10%, to the load used in the submaximal weight of the 5-10 reps done previously in the beginning of the warm up; two-minute rest; estimate a near maximal load that allowed subject to complete 2-3 repetitions by adding 10-20 pounds (4.5-9kg), or 5-10%, to the previous load; two- to four-minute rest. Subject performed a 1RM attempt by increasing the load used in step e by 10-20 pounds (4.5-9kg), or 5-10% followed by a two- to four-minute rest.

If subject failed 1RM attempt, we decreased the load by removing 5-10 pounds (2.3-4.5kg), or 2.5-5%, and had the subject perform one repetition followed by a two- to four-minute rest. We continued increasing or decreasing the load until the subject completed 1RM with appropriate technique. The subject’s 1RM should was achieved within 5 attempts.

In addition, a Clifton handgrip dynamometer (Clifton Therapeutic Instrument Company; Clifton, New Jersey) was used to measure static strength. The handle of the dynamometer was adjusted for proper fit, so that the base of the dynamometer rested on the first metacarpal and handle rested on the middle four fingers. The subject was asked to hold the handgrip dynamometer with his arm at a right angle and the elbow at the side of the body (Fiutko, 1987). The subject then squeezed the dynamometer with maximum isometric effort, which was maintained for about 5 seconds. This measure was repeated with each hand three times.
10 yard dash

The test is easy to set up and measures a person ability to accelerate. The test may provide information about an athlete’s ability to accelerate quickly, especially because much time can be lost during this phase, requiring a fast reaction off the line to get a better score time (Triplett, 2012). Inside the octagon where MMA bout takes place has a distance of 30 feet which is about 10 yards. The test-retest reliability for the 10-yard sprint test is .89 (Triplett, 2012). Main objective is to cover the distance as quickly as possible. Four or five trials with two- or three-minute rests between were performed. Can be tested at a track or field where distance can be measured. Equipment needed are tape measure, stop watch or timing gates, cones or tape to indicate start and finish lines, personnel at the finish line or at both the start and finish lines. We used stop watch. See Appendix D for procedure protocol.

Modified hand wall toss test (hand and eye coordination) (Session 2)

The Mackenzie (2009) hand and eye coordination test was used to assess subjects. A mark is placed a certain distance from the wall (e.g. 3 feet). Additionally, full length extension of arm and hand is pointed forward behind the 3 feet measuring tape placed on ground. Equipment needed are a tennis ball or baseball, smooth and solid wall, marking tape, and stop watch. See Appendix D for procedure protocol.
Modified bass test (assesses postural stability)

The modified bass test is a landing test to assess postural stability. The test has moderate reliability, requires minimal specialized equipment, and testing performance is linked to injury. The reliability is moderate (ICC = .70 to .74; Riemann, Caggiano, & Lephart, 1999) to high (ICC = .87; Eechaute, Vaes, & Duquet, 2009). This multiple hop test requires that 1-inch (2.5cm) tape squares be laid out in a course. Equipment needed are an athletic or masking tape. See Appendix D for procedure protocol.

1RM (or 2-5RM) bilateral back squat

The test retest correlations of between .92 and .99 have been reported for 1RM back squat loads reliability (Moir, 2012) Moderate ($r = .47$) to very large ($r = .85$) correlations between 1RM back squat loads and measures of athletic performance such as sprinting and agility have been reported for validity (Moir, 2012). 1RM squats have been shown to predict playing time in collegiate basketball and discriminate among playing positions within American football and basketball as well as differentiate playing levels in collegiate American football (Carbuhn et al. 2008; Latin et al. 1994; Fry & Kraemer 1991; Hoffman et al. 1996). Procedure used to test and assess 1RM of back squat was by Baechle, Earle, and Wathen (2008). See Appendix D for procedure protocol.
Weighted chin-up

Procedure used to test and assess 1RM of weighted chin-up will was by Baechle, Earle, and Wathen (2008), the same protocol used for bench press mentioned previously. See Appendix D for procedure protocol.

Bilateral back squat (65% of 1RM, 3 sets, 30 second rest) to failure

According to Heyward (2010) and Moir (2012) you can assess dynamic muscular endurance by having an individual perform as many repetitions as possible using a weight that is a set percentage of the maximum strength (1RM). Pollock, Wilmore, and Fox (1978) recommend using a weight that is 70% of the 1RM value for each exercise. Baker (2009) chose 60% of 1RM on well trained rugby league players. For this project, 65% of the subjects 1RM was assessed and according to Baechle and Earle (2006) the number of repetitions allowed should be around 15. Subject’s warmed up by completing 5-10 repetitions of a sub-maximal weight (50% of 1RM) followed by one-minute rest. Subject was then asked to perform as many repetitions as possible with 65% of their 1RM followed by thirty-second rest period. Subject immediately resumed repetitions until failure for a total of 3 sets.

Bench press (65% of 1RM, 3 sets, 30 second rest) to failure

Subject warmed up by completing 5-10 repetitions of a sub-maximal weight (50% of 1RM) followed by one-minute rest. Subject was then asked to perform as many
repetitions as possible with 65% of their 1RM followed by thirty-second rest period. Subject immediately resumed repetitions until failure for a total of 3 sets.

**Pull-up test**

High test-retest correlation coefficients (<.83) have been reported for pull-up test in male and female school children (Engelman & Morrow, 1991). However, there are no published data assessing the reliability of the test for adults and the width that the hands should be placed apart is not always specified in the published literature (Moir, 2012). This variable could greatly affect the reliability of the test and should be controlled by examiner. Procedure for pull-up test is by Hoffman (2006) with the addition of a supinated grip shoulder width apart. Williford et al. (1999) found that the number of pull-ups performed before failure was found to be a strong indicator of performance during specific firefighting task in a group of firefighters. See Appendix D for procedure protocol.

**Statistical Analysis**

This project was a descriptive evaluation of mixed martial art athlete’s anthropometric and physical characteristics. All data were tested for their normal distribution (Kolmogorov-Smirnov test). Assumptions of normality were not violated according to the Kolmogorov-Smirnov test for the anthropometric and physical characteristic tests. Data was interpreted in a descriptive manner and presented as a mean
± standard deviation (SD) for anthropometrics and somatotyping for the participants. Where possible, the muscular fitness test data was compared with normative data for the general population. Furthermore, these descriptive data were used to generate normative reference values (like Norm) for MMA fighters by classifying the athletes into the high (top 30%), the next as medium (middle 40%), and the low (bottom 30%).

The somatotype calculation and analysis software version 1.1 (San Diego, CA, USA) was used to plot the somatotype in Microsoft Excel software 2010 and calculate the frequencies in somatotype categories. In addition, all data for the skill-related physical test characteristics obtained in the field testing were presented as a mean ± standard deviation (SD) using K-means clustering analysis. Consent to the cluster analysis, a one-way ANOVA was used to determine if there were mean differences in the skill-related fitness measures and the win-loss percentage between the clusters groups identified. Finally, an independent t-test was used to determine if there was a significant difference in the skill-related physical fitness test measures and the win-loss percentage between the amateur and professional MMA athletes. Statistical analysis was carried out using IBM SPSS Statistics for Windows, Version 23.0.
RESULTS

Results are reported as the mean ± standard deviation for the anthropometric and physical characteristics. Assumptions of normality were not violated, according to the Kolmogorov-Smirnov test for health-related and skill-related physical fitness tests and somatotype ($p > 0.05$, respectively). For the muscular fitness and skill-related physical fitness test components, results are reported as the mean ± standard deviation and in the skill-related physical fitness test components, results are also reported as the mean ± standard deviation from k-means clustering. A total of 30 healthy male MMA athletes volunteered for this study, 17 professional and 13 amateurs; all 30 subjects completed the study. Subjects participated in anthropometric and skill-related physical fitness test components. All 30 subjects participated in somatotype measurements and the skill-related test components, however, 16 participated in %BF, 12 subjects for 1RM back squat and weighted chin-up (with 3 subjects using sub-maximum to estimate 1RM), 21 subjects for 1RM bench press (with 3 subjects using submaxim to estimate 1RM), 14 subjects for 1RM handgrip, 8 subjects for 65%RM back squat, twelve subjects for 65%RM bench press, and 25 subjects for the pull-up test. The anthropometrics and physical characteristics of the participants are summarized in Tables 8 – 15.

Anthropometric Characteristics
Anthropometrics, somatotype, and experience characteristics of MMA athletes

Anthropometric measurements of the fighters are found in Table 9, and Figures 1 and 2. The mean %BF of the MMA athletes was 9.7 ± 2.5, which is ranked above the 83 percentile and classified as excellent relative to general population norms (Cooper Institute, 2009). The mean Somatotype characteristic measurements of the fighters are found in Table 9. The mean somatotype reported from this project was: 3.4 ± 1.1 - 6.2 ± 1.6 - 1.9 ± 0.9, which is characterized as endomorphic-mesomorph (mesomorphy is dominant and endomorphy is greater than ectomorphy). Four skinfold measurements for somatotype were taken with the following observed mean values: 9.8 ± 3.3 mm (triceps), 14.7 ± 6.1 mm (subscapular), 9.6 ± 3.5 mm (suprailiac), and 6.5 ± 2.6 mm (medial calf). Two bone breadth measurements were taking with the following observed mean values: 7.4 ± 0.6 mm (humerus) and 9.8 ± 0.8 mm (femur). Two circumference measurements were taking with the following observed mean values: 37.1 ± 3.7 cm (biceps) and 37.4 ± 2.7 cm (calf).
Table 8. Weight classes of the participants (N=30)

<table>
<thead>
<tr>
<th>Weight class name</th>
<th>N = 30</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw weight</td>
<td>1</td>
<td>52</td>
</tr>
<tr>
<td>Flyweight</td>
<td>2</td>
<td>57</td>
</tr>
<tr>
<td>Bantamweight</td>
<td>3</td>
<td>61</td>
</tr>
<tr>
<td>Featherweight</td>
<td>6</td>
<td>66</td>
</tr>
<tr>
<td>Lightweight</td>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>Welterweight</td>
<td>7</td>
<td>77</td>
</tr>
<tr>
<td>Middleweight</td>
<td>1</td>
<td>84</td>
</tr>
<tr>
<td>Light heavyweight</td>
<td>2</td>
<td>93</td>
</tr>
<tr>
<td>Heavyweight</td>
<td>1</td>
<td>120</td>
</tr>
</tbody>
</table>
Table 9. Anthropometric and somatotype characteristics and experience of the participants (N=30)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Median</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>30</td>
<td>26.0</td>
<td>6.0</td>
<td>25.5</td>
<td>46.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>30</td>
<td>177.0</td>
<td>8.0</td>
<td>177.7</td>
<td>196.0</td>
<td>160.0</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>30</td>
<td>80.5</td>
<td>12.9</td>
<td>80.2</td>
<td>126.1</td>
<td>60.8</td>
</tr>
<tr>
<td>Body mass index</td>
<td>30</td>
<td>25.6</td>
<td>3.3</td>
<td>25.1</td>
<td>38.8</td>
<td>22.4</td>
</tr>
<tr>
<td>Endomorph</td>
<td>30</td>
<td>3.4</td>
<td>1.1</td>
<td>3.2</td>
<td>6.9</td>
<td>1.8</td>
</tr>
<tr>
<td>Mesomorph</td>
<td>30</td>
<td>6.2</td>
<td>1.6</td>
<td>5.9</td>
<td>13.1</td>
<td>4.4</td>
</tr>
<tr>
<td>Ectomorph</td>
<td>30</td>
<td>1.9</td>
<td>0.9</td>
<td>1.9</td>
<td>3.8</td>
<td>0.3</td>
</tr>
<tr>
<td>HWR</td>
<td>30</td>
<td>41.2</td>
<td>1.7</td>
<td>41.4</td>
<td>43.6</td>
<td>36.0</td>
</tr>
<tr>
<td>Experience training (yr)</td>
<td>30</td>
<td>8.0</td>
<td>5.0</td>
<td>5.5</td>
<td>20.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Experience competing (yr)</td>
<td>30</td>
<td>5.0</td>
<td>4.0</td>
<td>4.0</td>
<td>15.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Note.* HWR = height weight ratio
Figure 1. Somatotype mean of each participant (N=30)
Figure 2. Somatotype mean of the participants (N=30)
Muscular fitness and skill-related physical characteristics of MMA athletes

Physical Characteristics of MMA athletes are found in Tables 10 – 15. Tables 10 – 13 show muscular fitness and skill-related performance test results of the athletes categorized in high, medium, and low. The bench press (1RM/BM) mean was 1.34 (ranked in the 83 percentile and classified as excellent vs general population norms (Cooper Institute, 2009)). Handgrip isometric strength in this project produced mean values of 55.1 ± 11.1 with the right hand (classified as average), 55.1 ± 12 with the left (classified as average), and combined isometric strength was 110.2 ± 22.8 (classified as very good). The mean upper body muscular endurance measured using the pull-up test reported was 20.1 ± 4.2 repetitions, which is classified above excellent according to the American Alliance for Health, Physical Education, recreation and Dance (AAHPERD, 1976). Assessing upper body power using a modified seated medicine ball put, this project reported a mean value of 24.2 ± 3.5 feet.
Table 10. Descriptive values for strength and endurance for back squat

<table>
<thead>
<tr>
<th>Squat</th>
<th>1RM</th>
<th>1RM/BM</th>
<th>1st Set</th>
<th>T. REPS</th>
<th>1st Set Load</th>
<th>T. Load Vol.</th>
<th>T. Load Vol./BM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>REPS</td>
<td>Vol.</td>
<td>T.</td>
<td>Vol./BM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>12</td>
<td>12</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>High</td>
<td>&gt;161.0</td>
<td>&gt;1.81</td>
<td>&gt;25.0</td>
<td>&gt;42.0</td>
<td>&gt;3570.0</td>
<td>&gt;3722.7</td>
<td>&gt;58.9</td>
</tr>
<tr>
<td>Medium</td>
<td>136.0-161.0</td>
<td>1.65-1.81</td>
<td>16.0-25.0</td>
<td>29.0-42.0</td>
<td>3750.0-3750.0</td>
<td>3295.5-3722.7</td>
<td>37.3-58.9</td>
</tr>
<tr>
<td>Low</td>
<td>&lt;136.1</td>
<td>&lt;1.65</td>
<td>&lt;16.0</td>
<td>&lt;29.0</td>
<td>&lt;3750.0</td>
<td>&lt;3295.5</td>
<td>&lt;37.3</td>
</tr>
<tr>
<td>Mean</td>
<td>152.3</td>
<td>1.8</td>
<td>22.4</td>
<td>39.0</td>
<td>3904.3</td>
<td>3562.5</td>
<td>47.5</td>
</tr>
<tr>
<td>SD</td>
<td>36.4</td>
<td>0.2</td>
<td>12.2</td>
<td>16.0</td>
<td>1176.0</td>
<td>1119.6</td>
<td>14.5</td>
</tr>
<tr>
<td>Median</td>
<td>147.4</td>
<td>1.8</td>
<td>18.5</td>
<td>34.5</td>
<td>3660.0</td>
<td>3504.5</td>
<td>42.7</td>
</tr>
<tr>
<td>Maximum</td>
<td>247.2</td>
<td>2.0</td>
<td>50.0</td>
<td>72.0</td>
<td>5750.0</td>
<td>5227.3</td>
<td>67.8</td>
</tr>
<tr>
<td>Minimum</td>
<td>106.6</td>
<td>1.4</td>
<td>11.0</td>
<td>24.0</td>
<td>3210.0</td>
<td>1854.5</td>
<td>28.4</td>
</tr>
</tbody>
</table>

*Note.* Weight is in Kilograms; 1RM = one repetition maximum; BM = body mass; n = population; SD = standard deviation; 1RM/BM = weight ratio; REPS = repetitions; T. = total; Vol. = volume; > = greater than; < = less than.
Table 11. Descriptive values for strength and endurance for bench press

<table>
<thead>
<tr>
<th>Squat</th>
<th>1RM</th>
<th>1RM/BM</th>
<th>1st Set</th>
<th>T. REPS</th>
<th>1st Set Load</th>
<th>T. Load Vol.</th>
<th>T. Load Vol./BM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>REPS</td>
<td>Vol.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>21</td>
<td>21</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>High</td>
<td>&gt;120.2</td>
<td>&gt;1.46</td>
<td>&gt;17.0</td>
<td>&gt;28.0</td>
<td>&gt;1390.9</td>
<td>&gt;2063.4</td>
<td>&gt;25.3</td>
</tr>
<tr>
<td>Medium</td>
<td>97.5-120.2</td>
<td>1.17-1.46</td>
<td>14.0-17.0</td>
<td>25.0-28.0</td>
<td>954.5-1390.9</td>
<td>1813.6-2063.4</td>
<td>21.1-25.3</td>
</tr>
<tr>
<td>Low</td>
<td>&lt;97.5</td>
<td>&lt;1.17</td>
<td>&lt;14.0</td>
<td>&lt;25.0</td>
<td>&lt;954.5</td>
<td>&lt;1813.6</td>
<td>&lt;21.1</td>
</tr>
<tr>
<td>Mean</td>
<td>108</td>
<td>1.3</td>
<td>15.9</td>
<td>26.2</td>
<td>1160.6</td>
<td>1887.7</td>
<td>22</td>
</tr>
<tr>
<td>SD</td>
<td>25.6</td>
<td>0.2</td>
<td>3.4</td>
<td>4.9</td>
<td>291.5</td>
<td>283.3</td>
<td>3.8</td>
</tr>
<tr>
<td>Median</td>
<td>102.1</td>
<td>1.3</td>
<td>15.5</td>
<td>26.5</td>
<td>1180.7</td>
<td>1929.5</td>
<td>21.7</td>
</tr>
<tr>
<td>Maximum</td>
<td>183.7</td>
<td>1.7</td>
<td>24</td>
<td>35</td>
<td>1597.7</td>
<td>2290.9</td>
<td>27</td>
</tr>
<tr>
<td>Minimum</td>
<td>70.3</td>
<td>0.9</td>
<td>10</td>
<td>15</td>
<td>727.3</td>
<td>1288.6</td>
<td>14.3</td>
</tr>
</tbody>
</table>

Note. Weight is in Kilograms. 1RM = one repetition maximum; BM = body mass; n = population; SD = standard deviation; 1RM/BM = weight ratio; REPS = repetitions; T. = total; Vol. = volume; > = greater than; < = less than.
Table 12. Descriptive values for strength for Weighted Chin-Up

<table>
<thead>
<tr>
<th>Squat</th>
<th>1RM</th>
<th>1RM/BM</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>High</td>
<td>&gt;61.2</td>
<td>&gt;.75</td>
</tr>
<tr>
<td>Medium</td>
<td>47.6-61.2</td>
<td>.55-.75</td>
</tr>
<tr>
<td>Low</td>
<td>&lt;47.6</td>
<td>&lt;.55</td>
</tr>
<tr>
<td>Mean</td>
<td>53.7</td>
<td>0.7</td>
</tr>
<tr>
<td>SD</td>
<td>13.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Median</td>
<td>54.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Maximum</td>
<td>74.8</td>
<td>1</td>
</tr>
<tr>
<td>Minimum</td>
<td>22.7</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Note. Weight in kilograms. n = population; SD = standard deviation; > = greater than; < = less than; 1RM = one repetition maximum; / = divided by; BM = body mass
Table 13. Descriptive values for the physical characteristics

<table>
<thead>
<tr>
<th>Tests</th>
<th>N</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Mean</th>
<th>SD</th>
<th>Median</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Body Fat</td>
<td>16</td>
<td>&gt;8.3</td>
<td>11.0-8.3</td>
<td>&lt;11.0</td>
<td>9.7</td>
<td>2.5</td>
<td>9.4</td>
<td>15.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Handgrip Right</td>
<td>14</td>
<td>&gt;58.5</td>
<td>54.5-68.5</td>
<td>&lt;54.5</td>
<td>55.1</td>
<td>11.1</td>
<td>56.3</td>
<td>74.5</td>
<td>35.0</td>
</tr>
<tr>
<td>Handgrip Left</td>
<td>14</td>
<td>&gt;61.0</td>
<td>53.0-61.0</td>
<td>&lt;53.0</td>
<td>55.1</td>
<td>12</td>
<td>56.8</td>
<td>75.3</td>
<td>35.5</td>
</tr>
<tr>
<td>Handgrip Combined</td>
<td>14</td>
<td>&gt;119.5</td>
<td>107.0-119.5</td>
<td>&lt;107.0</td>
<td>110.2</td>
<td>22.8</td>
<td>113.8</td>
<td>149.8</td>
<td>70.5</td>
</tr>
<tr>
<td>Pull-Up</td>
<td>25</td>
<td>&gt;23.0</td>
<td>19.0-23.0</td>
<td>&lt;19.0</td>
<td>20.1</td>
<td>4.2</td>
<td>20.0</td>
<td>30.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Hand Wall Toss</td>
<td>30</td>
<td>&gt;35.0</td>
<td>31.0-35.0</td>
<td>&lt;31.0</td>
<td>32.4</td>
<td>4.3</td>
<td>32.0</td>
<td>42.0</td>
<td>24.0</td>
</tr>
<tr>
<td>BESS</td>
<td>30</td>
<td>&lt;10.0</td>
<td>17.0-10.0</td>
<td>&gt;17.0</td>
<td>13.0</td>
<td>7.0</td>
<td>12.5</td>
<td>33.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Modified Bass</td>
<td>30</td>
<td>&lt;3.0</td>
<td>6.0-3.0</td>
<td>&gt;6.0</td>
<td>4.7</td>
<td>5.9</td>
<td>3.0</td>
<td>23.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Hexagon</td>
<td>30</td>
<td>&lt;10.32</td>
<td>11.13-10.32</td>
<td>&gt;11.13</td>
<td>10.9</td>
<td>1.3</td>
<td>10.8</td>
<td>14.1</td>
<td>9.1</td>
</tr>
<tr>
<td>Broad Jump</td>
<td>30</td>
<td>&gt;9.0</td>
<td>7.9-9.0</td>
<td>&lt;7.9</td>
<td>8.4</td>
<td>0.9</td>
<td>8.6</td>
<td>10.0</td>
<td>6.9</td>
</tr>
<tr>
<td>Seated Med Ball</td>
<td>9</td>
<td>&gt;26.5</td>
<td>22.8-26.5</td>
<td>&lt;22.8</td>
<td>24.2</td>
<td>3.5</td>
<td>24.2</td>
<td>28.7</td>
<td>17</td>
</tr>
<tr>
<td>10-Yard Dash</td>
<td>30</td>
<td>&lt;1.71</td>
<td>1.84-1.71</td>
<td>&gt;1.84</td>
<td>1.8</td>
<td>0.1</td>
<td>1.7</td>
<td>2.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Note. #E = points of error; secs = seconds; #C = number of catches; ft. = feet; > = greater than; < = less than; BESS = Balance Error Scoring System.
K-Means clusters summary of the skill-related test and BMI on MMA athletes

Skill-Related Physical Characteristics of MMA athletes using K-means clustering are found in Tables 14-15 and Figure 3. Physical characteristics of the skill-related performance test and BMI were assessed using K-means cluster analysis with all 30 subjects. Cluster 1 had a total of 6 subjects (6 amateurs and 2 professionals). Cluster 2 had a total of 22 subjects (7 amateurs and 15 professionals).
Table 14. Final Cluster Centers

<table>
<thead>
<tr>
<th>Skill-related components</th>
<th>Test</th>
<th>N</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>1 vs. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance &amp; steadiness</td>
<td>BESS (#E)</td>
<td>30</td>
<td>21.5</td>
<td>11.23</td>
<td>1 &lt; 2</td>
</tr>
<tr>
<td>Balance &amp; stability</td>
<td>Modified Bass (#E)</td>
<td>30</td>
<td>11.38</td>
<td>2.32</td>
<td>1 &lt; 2</td>
</tr>
<tr>
<td>Agility</td>
<td>Hexagon (secs)</td>
<td>30</td>
<td>12.14</td>
<td>10.46</td>
<td>1 &lt; 2</td>
</tr>
<tr>
<td>Power</td>
<td>Broad jump (ft.)</td>
<td>30</td>
<td>7.73</td>
<td>8.66</td>
<td>1 &lt; 2</td>
</tr>
<tr>
<td>Speed</td>
<td>10 Yard dash (secs)</td>
<td>30</td>
<td>1.86</td>
<td>1.73</td>
<td>1 &lt; 2</td>
</tr>
<tr>
<td>Coordination</td>
<td>Hand wall toss (#C)</td>
<td>30</td>
<td>27.75</td>
<td>33.77</td>
<td>1 &lt; 2</td>
</tr>
<tr>
<td>Body mass Index</td>
<td>BMI</td>
<td>30</td>
<td>25.72</td>
<td>25.59</td>
<td>1 ~ 2</td>
</tr>
</tbody>
</table>

*Note. #E = points of error; secs = seconds; #C = number of catches; vs. = versus; > = greater than; < = less than; ~ = similar.*
Figure 3. Final Cluster Centers
The ANOVA table found in table 15 showed the largest significant differences observed between clusters 1 and 2 was the skill-related test component balance and steadiness (Modified Bass test) \( F = 25.585, p = 0.000 \) and the least significance was speed (10-yard dash) \( F = 7.724, p = 0.010 \). BMI was not significantly different between clusters 1 and 2. In addition, the largest error was seen in the Bess test (mean square = 29.209, \( df = 28 \)) and the least error was seen in the 10-yard dash (mean square = .012, \( df = 28 \)).
Table 15. ANOVA mean significant difference between the 2 cluster groups

<table>
<thead>
<tr>
<th>Skill-related components</th>
<th>Test</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance &amp; steadiness</td>
<td>Bess</td>
<td>21.195</td>
<td>0.000</td>
</tr>
<tr>
<td>Balance &amp; stability</td>
<td>Modified Bass</td>
<td>25.585</td>
<td>0.000</td>
</tr>
<tr>
<td>Agility</td>
<td>Hexagon</td>
<td>13.609</td>
<td>0.001</td>
</tr>
<tr>
<td>Power</td>
<td>Broad jump</td>
<td>8.694</td>
<td>0.006</td>
</tr>
<tr>
<td>Speed</td>
<td>10 Yard dash</td>
<td>7.724</td>
<td>0.010</td>
</tr>
<tr>
<td>Coordination</td>
<td>Hand wall toss</td>
<td>18.894</td>
<td>0.000</td>
</tr>
<tr>
<td>Body mass Index</td>
<td>BMI</td>
<td>0.008</td>
<td>0.927</td>
</tr>
</tbody>
</table>

Independent T-tests between groups of the skill-related test on MMA athletes

An independent-samples- t-test was conducted to compare the skill-related performance measures between elite athletes and amateur athletes, which is found in Table 16. There was a significant difference in the scores on agility (hexagon test) between elite level participants ($M = 10.44$, $SD = 0.86$) and amateur level participants ($M = 11.51$, $SD = 1.60$). This difference was significant $t (17.18) = 2.17, p = 0.044$. These results suggest that elite athletes have better agility than amateur level participants. There was a significant difference in the scores on lower body power (standing broad jump test) between elite level participants ($M = 8.71$, $SD = 0.73$), and amateur level participants ($M = 8.02$, $SD = 0.90$). This difference was significant $t (28) = -2.31, p = 0.028$. These results suggest that elite athletes have greater lower body power than amateur level participants.
Lastly, there was a significant difference in the scores on the coordination (hand wall toss test) between elite level participants ($M = 33.59, SD = 3.06$) and amateur level participants ($M = 30.31, SD = 4.99$). This difference was significant $t(28) = -2.22, p = 0.034$. These results suggest that elite athletes have greater hand and eye coordination than amateur level participants. However, there were no significant differences between the elite and amateurs in BMI, the balance and steadiness (BESS), balance and stability (Modified Bass), speed (10-yard dash), and win-loss percentages. Generally speaking, in summary these results suggest that elite athletes have better agility, power, and hand and eye coordination than amateur athletes in the sport of MMA.
Table 16. Independent T-tests between groups

<table>
<thead>
<tr>
<th>Test</th>
<th>Amateur</th>
<th>Professional</th>
<th>( p )</th>
<th>LSRF</th>
<th>HSRF</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>24.51 (2.44)</td>
<td>26.49 (3.75)</td>
<td>0.110</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexagon</td>
<td>11.51 (1.60)</td>
<td>10.44 (0.86)*</td>
<td>0.044</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broad Jump</td>
<td>8.02 (0.90)</td>
<td>8.71 (0.73)*</td>
<td>0.028</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand Wall</td>
<td>30.31 (4.99)</td>
<td>33.59 (3.06)*</td>
<td>0.034</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BESS</td>
<td>15.77 (8.43)</td>
<td>12.59 (5.65)</td>
<td>0.266</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mod. Bass</td>
<td>6.77 (7.37)</td>
<td>3.18 (4.03)</td>
<td>0.131</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-Yard</td>
<td>1.79 (0.11)</td>
<td>1.75 (0.13)</td>
<td>0.381</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winning %</td>
<td></td>
<td>68.7 (21.0)</td>
<td>79.0 (12.9)</td>
<td>0.110</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. * \( p < .05; \) LSRF = Lower Skill Related Fitness; HSRF = Higher Skill-Related Fitness; BMI = Body Mass Index; BESS = balance error scoring system; Mod. = modified
DISCUSSION

This project was conducted to investigate the anthropometric and physical characteristics of experienced MMA athletes. Measurements in this project included: body composition, somatotype, muscular strength, muscular endurance, balance and steadiness, balance and stability, agility, power, and coordination. Evaluation of the results of this study combined with previous studies on MMA athletes may help fill in the gaps to the missing skill-related performance tests and somatotyping to complete an athletic profile of the sport of MMA and its participants. As mentioned earlier the development of an athletic profile that may allow coaches and athletes: better judging of the effectiveness of a training plan; optimize overall physical and mental preparation for competition day; evaluate potential for overtraining or undertraining (overtraining syndrome); identify strengths and weaknesses and create training objectives; and classify skill status, body type, and ability level (Hoffman, 2011).

Muscular Fitness Test

Anthropometrics in MMA athletes

As mentioned earlier, MMA athletes that possess leaner muscle mass may enable them to generate more force in a short period of time, contributing to agility, quickness, and speed performance (Ratamess, 2012). Franchini et al (2014) found that a higher %BF is negatively correlated with performance in activities with body mass locomotion and
that successful performance in activities that require the application of force against external objects is positively related to the amount of absolute fat free BM and body size (Schick et al., 2010). The results in measurements in this project for %BF of the MMA athletes was a much lower level of %BF in comparison to the previous literature (table 2). In comparison to other combat sports (Gochioco et al., 2010; Gochioco et al., 2011; Schick et al., 2010) that are heavily incorporated in MMA, this project results of MMA subjects are also lower levels of %BF suggesting that having a low %BF may be vital for success in MMA. This significant difference may be due to this project having a much larger sample size of participants, higher level of competition, and what period they were in their training camps or competition period. It is important to note that %BF of MMA fighters in this project was assessed on 16 out of the total of 30 participants, and that many methods are available for body composition estimation, thus, it is difficult to standardize the measurements. Future studies should perform the same test and equation used in this study and contribute to establishing a strong foundation to develop normative data on MMA athletes.

**Somatotype in MMA athletes** 

This project shows that MMA athletes differ significantly from general and mainstream sport reference populations, and tend to exhibit specific characteristics of body form and composition necessary for MMA competition. The main findings of this project were that MMA athletes have predominantly mesomorphy and greater endomorphy than ectomorphy somatotype. To the best of our knowledge this project was
the first study to somatotype MMA athletes. In comparison to other combat sports, the results reported from this project were most similar to wrestlers, judokas and jiu jitsu athletes compared to boxers and kick boxers that all competed at international and national levels. This may be due to the fact that the duration of a MMA is predominantly grappling.

Franchini et al. (2014) depicts that in more complex sports where tactics and intricate techniques play a major role, the anthropometric profile does not always properly discriminate lower and higher level athletes. However, Lozovina & Lozovina (2008) asserts, “In sport-related human performance, physical structure is a necessary starting point for talent selection, the basis for the phenomenon known as morphological optimization, which aims to achieve optimal physical structure, body composition and somatotype for most efficient athletic performance in different sports”. It appears that the values found in this project suggest that dominant mesomorphic body types may be vital for success in MMA athletes, just like the other various combat sports heavily incorporated in MMA that have been studied. However, future studies should assess a wider variety of MMA athletes and compare anthropometrics and somatotype to different weight classes, dominant martial art discipline and fighting style to indicate a causal relationship.

**Muscular strength in MMA athletes**

As mentioned earlier, strength is important for MMA athletes for wrestling and grappling portions, takedowns, submissions, controlling opponents, and decreases the
probability of injury. Because MMA is a weight class sport, ideally the stronger opponent has a higher ability to contribute to performance enhancement of a decisive skill. This is because strength is the foundation on which power, agility, and speed is developed, and all three of these can end in a fight at any time or point during competition. The means for 1RM and 1RM/BM for back squat and bench press reported from this project were greater values in comparison to previous studies on MMA athletes. It is important to note that this project measured 12 out of the 30 participants 1RM strength for back squat and weighted chin-up. Greater 1RM bench press may be due to a larger sample size and higher competition level, 21 out of 30 participated in bench press, and 3 out of the 30 participants in this project performed a submaxim rather than 1RM. Because this project did not assess 1RM strength for back squat and bench press in all 30 participants it is difficult to compare the 2 at this time, however, future studies can use submaxim test no more than 5 repetitions and compare their results to this project.

The mean strength values in isometric grip test in this project are much greater than previous studies on MMA athletes and other combat sports that are heavily incorporated in MMA like boxers and wrestlers. This project greater grip strength for both right and left hand as well as combined grip strength in comparison to previous studies on MMA athletes as well as other combat sports may be due to having a much larger sample size of participants and higher level of competition, and what period they were in their training camps or competition.
Muscular endurance in MMA athletes

Due to repetitive striking combinations and submission attempts, MMA involves a lot of sustained movements, thus, showing the importance of muscular endurance (Gillis, 2013). The results from this project assessing muscular endurance on MMA athletes suggest that it is essential for MMA athletes to have excellent endurance to be triumphant in competition. This project also assessed bench press and back squat using an endurance test until failure using 65% of 1RM of MMA athletes for the first time.

Skill-Related Physical Test Components

The skill-related physical characteristics assessed and reported in this project were establish a reference for baseline value and the beginning to produce normative data, Thus, future studies should perform the same test and contribute to establishing a strong foundation to develop normative data on MMA athletes.

Skill-Related Physical Test Components Using K-means Clustering

Description of subject sample in cluster 1 vs. cluster 2

This project had 8 MMA subjects in cluster 1 (6 amateurs and 2 elites) and 22 MMA subjects in cluster 2 (7 amateurs and 15 elites). Cluster 1 had 2 elites that were welterweight and heavyweight weight class that have both competed around 7 years. 2 amateurs were featherweight that both had 2 years of competition experience, 1 bantamweight that had 2 years of experience, 1 flyweight that had 2 years of experience,
1 lightweight that had 4 years of experience, and 1 straw-weight that had 1 year of experience. The most notable differences between cluster 1 and 2 were mostly observed during the Modified Bass test, BESS test, Hand wall toss test, and Hexagon test. There were significant differences in the Standing Broad Jump and 10-Yard Dash, however not nearly as significant as the first four test. This may suggest that balance, hand and eye coordination, and agility are all good indicators when assessing MMA athlete’s physical characteristics. Even more notably, both balance test had the greatest significances, which may suggest how pertinent balance is in the sport demands of MMA. It’s important to note, that a majority of participants that were grouped in cluster 2 were in feather weight, light weight, and welterweight. In contrast, the majority of participants in cluster 1 were in the lightest weight classes and heaviest, which also may suggest significant differences between groups.

Balance in MMA athletes

Assessing balance and steadiness, a majority of the MMA subjects that participated in this project, specifically cluster 2 had a better score on the BESS test than cluster 1 (22 subjects in cluster 2, in contrast to cluster 1 that had 8 subjects). It is important to note that a higher score on the BESS test is not considered optimal. Normative data for the Bess test rank a score of 11.2 in the 25-75th percentile (Flanagan, 2012). The normative data in BESS scores are not normally distributed, therefore, the percentile ranks correspond to the natural distribution of scores, which has a huge range from 25-75th percentile with points of errors between 7 – 14. Thus, a core of 11 is directly
in the middle and may be assumed to be around the upper 50th percentile. From ages 20 – 39, with a population to be 104 subjects, normative data shows a mean to be 10.97 ± 5.05 in the BESS test, which is similar to what this project found in MMA subjects.

Assessing balance and stability, a majority of MMA athletes that participated in this project, specifically cluster 2 had a better score on the Modified Bass test than cluster 1. It is important to note that a higher score on the Modified Bass test is not considered optimal. Normative data from Riemann, Caggiano, and Lephart, (2010) report mean balance error to be 7.3 ± 5.9 and landing error to be 43.7 ± 23.3. This project reported combined mean of balance and landing error in the majority of MMA participants to be 2.32 points of error, which is far superior than Riemann et al. (1999) reported norms. Low scores in balance of MMA athletes may be due to their need to perform attacks and defenses in open and closed kinetic chain movement. Many strikes and takedowns are performed using one leg, as well needing the ability to regain balance after a launched attack or defense. In addition, many strikes and kicks are tri-planar which involves skillful movement and control of one’s body in order to be successful in competition.

Agility in MMA athletes

Assessing agility, a majority of the MMA subjects that participated in this project, specifically cluster 2 had a better score on the hexagon test than cluster 1. Descriptive data from Harman and Garhammer (2008) showed competitive college and recreational college male athletes to have a mean score of 12.3 seconds. This project reported mean of the hexagon test in the majority of MMA subjects to 10.46 seconds, which is superior to
both college and reactional athletes. Higher agility scores in MMA athletes may be due to their need to affectively react to opponents, either by evading an attack or launch an attack at an undefended area. MMA athletes that possess higher levels agility may better enable them to quickly maneuver and change positions or stances to effectively be triumphant in competition.

Power in MMA athletes

Assessing lower body power, a majority of MMA athletes that participated in this project, specifically cluster 2 had a better score on the standing broad jump test than cluster 1. This suggest that it may be imperative that MMA athletes possess a certain level of power that is essential for escaping dangerous position, executing successful striking and kicking combinations, and takedowns. In addition, ideally, the athlete that has more power has a higher probability of ending the fight, especially early in the round, thus power endurance may be of extreme importance for MMA athletes to be triumphant in competitions.

Speed in MMA athletes

Assessing speed or acceleration, a majority of MMA athletes that participated in this project, specifically cluster 2 had a better score on the 10-yard dash test than cluster 1. This suggest that MMA athletes that have a higher level of speed or acceleration have the ability to close the distance to their opponent and launch an effective attack or
takedown. Thus, the athlete that is quicker has a higher probability to be triumphant assuming they are techniquely sound in their skills as martial artist.

Coordination in MMA athletes

Assessing hand and eye coordination, a majority of MMA athletes that participated in this project, specifically cluster 2 had a better score on the hand wall toss test than cluster 1. According to normative data, cluster 2 score of 33 is classified above average (Mackenzie, 2016). This suggest that MMA athletes that have a higher level of hand and eye coordination may enable them to better shield themselves and attack opponents, which requires your eyes to focus on the fast moving individuals across you and respond with your hands. However, normative data from Mackenzie, 2016 assessed children around 16 years old, thus, future studies should perform the same test and contribute to establishing a strong foundation to develop normative data on MMA athletes.

Skill-Related Test Components Using Independent T-test Between Elite and Amateur MMA Athletes

This project showed significant differences between elite and amateur MMA fighters in agility, lower body power, and hand and eye coordination, but not win-loss percentage. This may suggest differences between professional and amateur MMA fighters is not so much of their win-loss records but their physical ability and athleticism
in certain performance test. As stated earlier, the fighters in Cluster 2 scored significantly
\( p < .05 \) better than those in Cluster 1 in all of the skill-related physical fitness test
components. In addition, an independent t-test revealed that elite fighters had
significantly better scores than amateurs for agility, power, and coordination. This may
suggest that these 3 skill-related physical fitness test components are good indicators for
the sport demands of MMA. Future studies should perform the same test between
professional and amateur to validate the significant differences found in this project.

Implications and Future Studies

This project brings attention to a sport that is growing exponentially and merits
more research. Results of this study exhibit the need for more investigations to validate
these results and differences in the outcome among individual weight classes (Siqueido,
2010). We suggest that in future studies the timing of the testing, such as day and time is
kept the same to promote consistency. It would be beneficial for future researchers to
follow MMA athletes over an extended period of time to better evaluate the changes in
anthropometrics and physical characteristics during their training camps. Coaches in the
field should be educated on the importance of developing an athletic profile by
incorporating a validated battery of fitness field testing into a MMA athletes training
schedule. Our project provides a reference for baseline values and initial norms for future
investigations where anthropometric and physical characteristics may be utilized to create
athletic profiles and strength training programs to prepare MMA fighters for the physical demands of their sport.
REFERENCES


APPENDIX A: INFORMED CONSENT

Humboldt State University Department of Kinesiology
Consent to Participate in Research

Health and Skill-Related Physical Fitness Characteristics of Mixed Martial Arts Athletes

Purpose and General Information
You are being asked to participate in a research study conducted by Uriah J. Maimone (Principle Investigator) and Young Sub Kwon, Ph.D. (Responsible faculty). The purpose of this research is to evaluate how to develop health and skill-related physical fitness tests for mixed martial arts (MMA) athletes. You are being asked to participate because you are MMA athletes who are healthy and between the ages of 18-49 years. Your data will not be shared with your coach or gym owner. This form will explain the study, including possible risks and benefits of participating, so you can make an informed choice about whether or not to participate. Please read this consent form carefully. Feel free to ask the investigators or study staff to explain any information that you do not clearly understand.

What will happen if I participate?
This proposed project will be developed based on science and theory in the fields of Exercise Science. All testing will take place in the Human Performance Lab (HPL) at Humboldt State University (HSU) or your gym facility. When scheduling takes place, you will be asked to refrain from using caffeine and alcohol for 24 hours before each testing and training session. If you agree to be included in this study, you will be asked to read and sign this consent form. Upon signing, the following will occur:

• The study will be described in detail and your questions will be answered, then you will fill out all pre-screening forms in a private room in the Human Performance Lab and your gym. You will be introduced to the study, the purposes and procedures, and the risks and benefits. Following this introductory information, a Health History and Activity Questionnaire, Physical Activity Readiness Questionnaire (PAR-Q) will be completed. The investigators will provide a detailed description of the protocol both verbally and in writing. You will be encouraged to ask questions.

• The period of this study is from July 20, 2015 thru July 19, 2016. Your skill-and fitness-related physical fitness will be assessed throughout this time period. Muscular fitness, cardiorespiratory endurance, flexibility, body composition, speed, power, agility, balance, coordination, anthropometric assessments will be completed.

• The risk of breaching confidentiality will be minimized by using only professional personnel to perform all study activities, identification numbers
instead of names, and rooms at times when others will not need access. A private room is available for discussion and testing, and all study data will be kept in a file cabinet in the P.I.’s office. All data will continue to be coded so that your identity is not revealed throughout the duration of the research.

- The length of time the participation will take around 2 hours.

**What are the possible risks or discomforts of being in this study?**
Every effort will be made to protect the information you give us. Every effort will also be made to minimize any risk by allowing proper warm-up. As with any research, there may be unforeseeable risks. These risks include muscle soreness, muscle fatigue, and common injuries associated with exercise like muscle pull, muscle strain, and sprained ankle, shin splint, etc.
For more information about risks, contact the responsible faculty, Young Sub Kwon, Ph.D. (ysk15@humboldt.edu, 707 826-5944)

**How will my information be kept confidential?**
Your name and other identifying information will be maintained in files, available only to authorized members of the research team for the duration of the study. For any information entered into a computer, the only identifier will be a unique study identification (ID) number. Any personal identifying information and record linking that information to study ID numbers will be destroyed when the study is completed. Information resulting from this study will be used for research purposes and may be published; however, you will not be identified by name in any publications.

**What other choices do I have if I don’t participate?**
Taking part in this study is voluntary so you can choose not to participate. The investigators have the right to end your participation in this study if they determine that you no longer qualify for various reasons such as health or injury issues, not following study procedures, or absenteeism.

**Will I be paid for taking part in this study?**
There will be no compensation.

**Can I stop being in the study once I began?**
Yes, you can withdraw from this study at any time without consequence.

**Protected health information (PHI)**
By signing this consent document, you are allowing the investigators and other authorized personnel to use your protected health information for the purposes of this study. This information may include: resting blood pressure, height, weight, age, %body fat, and health and fitness related items on the questionnaires. In addition to
researchers and staff at the Human Performance Lab (HPL) at Humboldt State University (HSU) and other groups listed in this form, there is a chance that your health information may be shared (re-disclosed) outside of the research study and no longer be protected by federal privacy laws. Examples of this include disclosures for law enforcement, judicial proceeding, health oversight activities and public health measures.

**Right to Withdraw**

Your authorization for the use of your health information shall not expire or change unless you withdraw or change that information. Your health information will be used as long as it is needed for this study. However, you may withdraw your authorization at any time provided you notify the Humboldt State University investigators in writing. To do this, please contact to:

Uriah J. Maimone. 310 704 7177 from Monday thru Friday 8am - 5pm.
ujm6@humboldt.edu Department of Kinesiology Humboldt State University
Please be aware that the research team will not be required to destroy or retrieve any of your health information that has already been used or shared before your withdrawal is received.

**Refusal to Sign**

If you choose not to sign this consent form, you will not be allowed to take part in the project.

**What if I have questions or complaints about this study?**

The investigator will answer any question you have about this study. Your participation is voluntary and you may stop at any time. If you have any questions, concerns, or complaints about this study, please contact Young Sub Kwon, Ph.D. If you would like to speak with someone other than the research team, you may call the chair of the Institutional Review Board (IRB) for the Protection of Human Subjects, Dr. Ethan Gahtan, at eg51@humboldt.edu or (707)826-4545. The IRB is a group of people from Humboldt State University and the community who provide independent oversight of safety and ethical issues related to research involving human subjects.

**Liability**

No compensation for physical injury resulting from participating in this research is available.

**What are my rights as a research projects?**
If you have questions about your rights as a participant, report them to the Humboldt State University Dean of Research, Dr. Rhea Williamson, at Rhea.Williamson@humobldt.edu or (707) 826-5169.

**Consent and Authorization**

You are making a decision whether to participate in this study. Your signature below indicates that you read the information provided (or the information was read to you). By signing this Consent Form, you are not waiving any of your legal rights as a research subject.

Sincerely,

Uriah J. Maimone.

I have read the consent form and had an opportunity to ask questions and all questions have been answered to my satisfaction. By signing this consent form, I agree to participate to this study and give permission for my health information to be used or disclosed as described in this consent form.

A copy of this consent form will be provided to me.

______________________________________________ _____________
Signature of participant   Date
**APPENDIX B: MEDICAL HISTORY & RELEASE OF LIABILITY**

**Humboldt State University Health and Wellness Institute Medical Information and History and Release of Liability**

<table>
<thead>
<tr>
<th>Name</th>
<th>__________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>__________________________</td>
</tr>
<tr>
<td>Home Phone</td>
<td>____________</td>
</tr>
<tr>
<td>Age</td>
<td>Date of Birth</td>
</tr>
<tr>
<td>____________</td>
<td>________________</td>
</tr>
</tbody>
</table>

The following questions are designed to help us tailor the health and fitness assessment and follow-up counseling to your personal situation. It is extremely important for us to know if you have any medical conditions which may affect your testing process or your progress in our program. Please take the time to answer these questions accurately.

**Medical History**

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>In the past five years have you had:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( )</td>
<td>( )</td>
<td>1. Pain or discomfort in chest, neck, jaw, or arms</td>
</tr>
<tr>
<td>( )</td>
<td>( )</td>
<td>2. Shortness of breath or difficulty breathing at rest or with mild exertion (e.g., walking)</td>
</tr>
<tr>
<td>( )</td>
<td>( )</td>
<td>3. Dizziness or fainting</td>
</tr>
<tr>
<td>( )</td>
<td>( )</td>
<td>4. Ankle edema (swelling)</td>
</tr>
<tr>
<td>( )</td>
<td>( )</td>
<td>5. Heart palpitations (forceful or rapid beating of heart)</td>
</tr>
<tr>
<td>( )</td>
<td>( )</td>
<td>6. Pain, burning, or cramping in leg with walking</td>
</tr>
<tr>
<td>( )</td>
<td>( )</td>
<td>7. Heart murmur</td>
</tr>
<tr>
<td>( )</td>
<td>( )</td>
<td>8. Unusual fatigue with mild exertion</td>
</tr>
</tbody>
</table>

Have you ever had:

| ( ) | ( ) | 9. Heart disease, heart attack, and/or heart surgery |
| ( ) | ( ) | 10. Abnormal EKG |
| ( ) | ( ) | 11. Stroke |
| ( ) | ( ) | 12. Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myxedema) |
| ( ) | ( ) | 13. Asthma or any other pulmonary (lung) condition |
| ( ) | ( ) | 14. Heart or blood vessel abnormality (e.g., suspected or
known aneurysm) ( ) ( )  15. Liver or kidney disease
( ) ( )  16. Are you currently under the care of a physician?
( ) ( )  17. Do you currently have an acute systemic infection, accompanied
by a fever, body aches, or swollen lymph glands?
( ) ( )  18. Do you have a chronic infectious disease (e.g. mononucleosis,
hepatitis, AIDS)? ( ) ( )  19. Do you have a neuromuscular,
musculoskeletal, or rheumatoid disorder that is
made worse by exercise?
( ) ( )  20. Do you have an implantable electronic device (e.g. pacemaker)?
( ) ( )  21. Do you know of any reason why you should not do physical activity?

If you answered yes to any of these questions, please explain.
Risk Factors

YES  NO  DON’T KNOW
(  ) (  ) (  ) 1. Are you a male 45 years of age or older?
(  ) (  ) (  ) 2. Are you a female 55 years of age or older?
(  ) (  ) (  ) 3. Do you have a father or brother who had a heart attack or heart surgery before age 55?
(  ) (  ) (  ) 4. Do you have a mother or sister who had a heart attack or heart surgery before age 65?
(  ) (  ) (  ) 5. Do you smoke or have you quit in the past 6 months?
(  ) (  ) (  ) 6. Do you have frequent secondhand smoke exposure?
(  ) (  ) (  ) 7. Do you know your blood pressure? mmHg-Date: (  ) (  ) (  )
(  ) (  ) (  ) 8. What is your total cholesterol? mg/dL-Date: (  ) (  ) (  )
(  ) (  ) (  ) 9. Are you taking cholesterol lowering medication?
(  ) (  ) (  ) 10. Do you know your HDL cholesterol? mg/dL-Date: (  ) (  ) (  )
(  ) (  ) (  ) 11. Is your HDL cholesterol > 60mg/dL?
(  ) (  ) (  ) 12. What is your fasting blood glucose? mg/dL – Date: (  ) (  ) (  )
(  ) (  ) (  ) 13. Do you exercise regularly? If so, explain.

If you answered yes to any of these questions, please explain.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Office Use

<table>
<thead>
<tr>
<th>BMI</th>
<th>SBP</th>
<th>DBP</th>
<th>TC</th>
<th>HDL</th>
<th>LDL</th>
<th>FBG</th>
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</thead>
<tbody>
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<td></td>
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</tr>
</tbody>
</table>

Family History Smoking Sedentary

Health-Related Questions

YES  NO
(  ) (  ) 1. Are you pregnant?
(  ) (  ) 2. Are you allergic to isopropyl alcohol (rubbing alcohol) or latex?
3. Do you have any allergies to medications, bees, foods, etc.? If so please list

4. Do you have any skin problems?

5. Do you have any other medical condition(s)/surgeries?

6. Have you had any caffeine, food, or alcohol in the past 3 hours? ( ) ( )

7. Have you exercised today?

8. Are you feeling well and healthy today?

9. Do you have any other medical concerns that we should be aware of?

If you answered yes to any of these questions, please explain.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Medications

Please Select Any Medications You Are Currently Using:

<table>
<thead>
<tr>
<th>Diuretics</th>
<th>Other Cardiovascular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta Blockers</td>
<td>NSAIDS/Anti-inflammatory (Motrin, Advil)</td>
</tr>
<tr>
<td>Vasodilators</td>
<td>Cholesterol</td>
</tr>
<tr>
<td>Alpha Blockers</td>
<td>Diabetes/Insulin</td>
</tr>
<tr>
<td>Calcium Channel Blockers</td>
<td>Birth Control</td>
</tr>
</tbody>
</table>

Please list the specific medications that you currently take:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

What are your health and fitness goals?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

I certify that the information I have provided is complete and accurate to the best of my knowledge.

Date ___________ Signature of Subject ______________________________________

Date ___________ Signature of Witness ______________________________________
___ Low Risk  ___Moderate Risk  ___High Risk
HUMBOLDT STATE UNIVERSITY RELEASE OF LIABILITY, PROMISE NOT TO SUE, ASSUMPTION OF RISK AND AGREEMENT TO PAY CLAIMS

I have read this form, and I understand the test procedures that I will perform and the attendant risks and discomforts. Knowing these risks and discomforts, and having had an opportunity to ask questions that have been answered to my satisfaction, I consent to participate in this test.

In consideration for being allowed to participate in this Activity, on behalf of myself and my next of kin, heirs and representatives, I release from all liability and promise not to sue the State of California, the Trustees of The California State University, California State University, Humboldt State University and their employees, officers, directors, volunteers and agents (collectively “University”) from any and all claims, including claims of the University’s negligence, resulting in any physical or psychological injury (including paralysis and death), illness, damages, or economic or emotional loss I may suffer because of my participation in this Activity, including travel to, from and during the Activity.

I am voluntarily participating in this Activity. I am aware of the risks associated with traveling to/from and participating in this Activity, which include but are not limited to physical or psychological injury, pain, suffering, illness, disfigurement, temporary or permanent disability (including paralysis), economic or emotional loss, and/or death. I understand that these injuries or outcomes may arise from my own or other’s actions, inaction, or negligence; conditions related to travel; or the condition of the Activity location(s). Nonetheless, I assume all related risks, both known or unknown to me, of my participation in this Activity, including travel to, from and during the Activity.

I agree to hold the University harmless from any and all claims, including attorney’s fees or damage to my personal property that may occur as a result of my participation in this activity, including travel to, from and during the Activity. If the University incurs any of these types of expenses, I agree to reimburse the University. If I need medical treatment, I agree to be financially responsible for any costs incurred as a result of such treatment. I am aware and understand that I should carry my own health insurance.

Date: __________ Signature of Subject: ____________________________

Date: __________ Signature of Witness: ____________________________
APPENDIX C: LETTERS OF APPROVAL

APC
CENTRE DE PERFORMANCE ADRENALINE
ADRENALINE PERFORMANCE CENTER

8158 Devonshire
TMR, PQ H4P 2K3
Phone 514 564 3538  Fax 514 564 3836
info@adrenalineperformancecenter.com

DATE: 6/18/15

Young Sub Kwon PhD, ACSM RCEP, NSCA CSCS*D
Past Kansas Representative, American College of Sports Medicine (ACSM)
Assistant Professor/Director Human Performance Lab
Department of Kinesiology & Recreation Administration
KA 328
1 Harpast Street, Arcata CA 95521

To whom it may concern:

This letter certifies that Principal Investigator Young Sub Kwon and Graduate student Uriah J. Maimone has permission to recruit The Mixed Martial Artist (MMA) members of Adrenaline Performance Center (APC) authority to participate in their project titled “Health & Skill-related Physical Fitness Components of Mixed Martial Artist”. We understand that Uriah J. Maimone will be collecting data here at APC Gym for the study and use some of the data collected for his project thesis at Humboldt State University, Arcata in the Department of Kinesiology. For any further questions or clarification, please feel free to contact us directly via email,
info@adrenalineperformancecenter.com

We (I) hereby give Uriah J. Maimone to advertise, recruit, and perform physiological testing to MMA athletes through the distribution and posting of flyers and word of mouth at APC Gym.

Sincerely,

[Signatures]

[Date]
The Body Shop Fitness Gym  
5839 Bellflower Blvd, Lakewood, CA 90713  
Phone 562 234 7950  
info@antonimckee@yahoo.com  

DATE: 1/03/16

Young Sub Kwon PhD, ACSM RCEP, NSCA CSCS*D  
Past Kansas Representative, American College of Sports Medicine (ACSM)  
Assistant Professor/Director Human Performance Lab Department of  
Kinesiology & Recreation Administration KA 328  
1 Harpa Street, Arcata CA 95521

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We (I) hereby give Uriah J. Maimone to advertise, recruit, and perform physiological testing to MMA athletes through the distribution and posting of flyers and word of mouth at Team Body Shop Fitness Gym.  
Sincerely,

\[ Signature \]  
\[ Date 1/20/2016 \]
APPENDIX D: METHODS OF PROCEDURES

SOMAOTYPE: HEATH CARTER


a. Stature (height): Taken against a height scale or stadiometer. Take height with the subject standing straight, against an upright wall or stadiometer, touching the wall with heels, buttocks and back. Orient the head in the Frankfort plane (the upper border of the ear opening and the lower border of the eye socket on a horizontal line), and the heels together. Instruct the subject to stretch upward and to take and hold a full breath. Lower the headboard or mark top of head.

b. Body mass (weight): The subject, wearing minimal clothing, stands in the center of the scale platform. Record weight to the nearest tenth of a kilogram. A correction is made for clothing so that nude weight is used in subsequent calculations.

c. Skinfolds: Raise a fold of skin and subcutaneous tissue firmly between thumb and forefinger of the left hand and away from the underlying muscle at the marked site. Apply the edge of the plates on the caliper branches 1 cm below the fingers of the left hand and allow them to exert their full pressure before reading at 2 secs the thickness of the fold. Take all skinfolds on the right side of the body. The subject stands relaxed, except for the calf skinfold, which is taken with the subject seated.
d. Triceps skinfold: With the subject's arm hanging loosely in the anatomical position, raise a fold at the back of the arm at a level halfway on a line connecting the acromion and the olecranon processes.

e. Subscapular skinfold: Raise the subscapular skinfold on a line from the inferior angle of the scapula in a direction that is obliquely downwards and laterally at 45 degrees.

f. Supraspinale skinfold: Raise the fold 5-7 cm (depending on the size of the subject) above the anterior superior iliac spine on a line to the anterior axillary border and on a diagonal line going downwards and medially at 45 degrees. (This skinfold was formerly called suprailiac, or anterior suprailiac. The name has been changed to distinguish it from other skinfolds called "suprailiac", but taken at different locations.)

g. Medial calf skinfold: Raise a vertical skinfold on the medial side of the leg, at the level of the maximum girth of the calf.

h. Biepicondylar breadth of the humerus, right: The width between the medial and lateral epicondyles of the humerus, with the shoulder and elbow flexed to 90 degrees. Apply the caliper at an angle approximately bisecting the angle of the elbow. Place firm pressure on the crossbars in order to compress the subcutaneous tissue.

i. Biepicondylar breadth of the femur, right: Seat the subject with knee bent at a right angle. Measure the greatest distance between the lateral and medial epicondyles of the femur with firm pressure on the crossbars in order to compress the subcutaneous tissue.
j. Upper arm girth, elbow flexed and tensed, right: The subject flexes the shoulder to 90 degrees and the elbow to 45 degrees, clenches the hand, and maximally contracts the elbow flexors and extensors. Take the measurement at the greatest girth of the arm.

k. Calf girth, right: The subject stands with feet slightly apart. Place the tape around the calf and measure the maximum circumference.

ANTHROPOMETRIC: BODY FAT PERCENTAGE

a. Skinfolds: Raise a fold of skin and subcutaneous tissue firmly between thumb and forefinger of the left hand and away from the underlying muscle at the marked site. Apply the edge of the plates on the caliper branches 1 cm below the fingers of the left hand and allow them to exert their full pressure before reading at 2 secs the thickness of the fold. Each site is measured 3 times, and if values are more than 10% off, additional measurements should be made. Take all skinfolds on the right side of the body.

b. Abdominal: Vertical fold; 2 cm to the right side of the umbilicus.

c. Chest: Diagonal fold; one-half the distance between the anterior axillary line and the nipple (men).

d. Thigh: Vertical fold; on the anterior midline of the thigh, midway between the proximal border of the patella and the inguinal crease (hip).

BALANCE AND STEADINESS: BESS TEST
Three stances (double-leg support, single leg-support, and tandem) are held for twenty seconds on two surfaces (firm floor and foam pad) for six permutations (Riemann, Guskiewicz, and Shields, 1999).

During the tandem stance, subject’s dominant foot is in front of the nondominant foot.

During the single-leg stance, subject stands on the nondominant foot.

b. During the test, subject’s eyes are closed, and their hands are held on the hips (iliac crest).

c. Subjects are instructed to keep as steady as possible, and if they lose their balance, they are to try to regain initial position as quickly as possible.

d. Subjects are assessed one point for the following errors: lifting hands off the hips; opening eyes; stepping, stumbling, or falling; remaining out of the test position for five seconds; moving hip into more than 30 degrees of hip flexion or abduction; or lifting forefoot or heel (Riemann, Guskiewicz, and Shields, 1999).

e. A trial is considered incomplete if the subject cannot hold the position without error for at least five seconds.

AGILITY: HEXAGON TEST

Instruct subject on correct performance of the test, following these steps:

b. Subject stands in the middle of the hexagon in an upright stance and faces forward.
c. Subject is given a countdown and starts the test by double-leg hopping from the center of the hexagon across one side of the hexagon and back inside. This is performed in a clockwise direction until each side of the hexagon is crossed and the entire hexagon is traversed a total of 3 times.

d. Subject must face the same direction for the entire test and should not land on a line or lose balance and take an extra step or fail to cross a line. If this occurs, the trial is stopped and restarted.

e. Start the watch at subject’s first movement and stop it when the subject returns to the center of the hexagon for the last time.

f. The best of three trials is recorded to the nearest 0.5 inch. Stop test at fourth jump, unless subject continues to increase speed.

LOWER BODY POWER: STANDING BROAD JUMP

Designate starting line using a three foot (1m) piece of masking tape.

b. Subject is instructed to warm-up after familiarization with SBJ test procedure, performing five minutes of moderate intensity aerobic exercise (jogging is preferred), followed by several dynamic and rapid range of motion for hip flexors and extensors, hamstrings, quadriceps, calves, and shoulders. Subject is allowed several SBJ trails at less-than-maximal effort.

c. Subject’s jump distance is measured and recorded. Toes should begin behind starting line before takeoff, using a rapid countermovement and then jumps forward as far
as possible. A marker is placed behind the subject’s rearmost heel, using a small piece of measuring tape.

d. The best of three trials is recorded to the nearest 0.5 inch. Stop test at fourth jump, unless subject continues to increase distance. The SBJ is recorded as the difference from the starting line and the longest jump.

UPPER BODY POWER: MODIFIED SEATED MEDICINE BALL PUT

Measuring tape is placed on the floor with the end positioned under subject whose back us upright against wall. Measuring tape is anchored by duct tape. Measuring tape should be positioned so that it is aligned with the outside of the medicine ball while it rests on subject’s chest and against wall (in ready position) (Clemons, Campbell, and Jeansonne, 2010). Tape should be extended outward from wall for at least eight meters (26 feet), and secured to floor.

b. Subject is instructed with putting procedure, and then performs five minutes of moderate intensity exercise, followed by dynamic range of motion exercises for shoulder, and elbow joint. The subject is then allowed several submaximal trails with medicine ball to become familiar with putting.

Important for the test, is that subject is seated comfortably back against the wall upright, feet bridged and flat on the floor out in front of body, and medicine ball against chest.
c. Subject grasps medicine ball with both hands, one on each side. Without any additionally bodily movement (e.g., trunk or neck flexion, arm countermovement), subject attempts to propel (i.e., “put”) medicine ball at optimal trajectory of 45 degrees, for maximal horizontal distance.

d. Every attempt by subject should be made to propel the ball in a straight line to obtain valid data. Three to five attempts and/or until subject fails to increase distance is permitted, with a minimum of two minutes of rest between attempts. Each test attempt should be measured by the closest to where ball stops rolling forward (i.e., direction of subject facing) and recorded to the nearest centimeter or inch.

SPEED: 10 YARD DASH

Instruct subject on correct technique performance of the test.

b. Subject lines up behind the start line, facing forward. Sport-specific stances can also be used, such as a three-point stance as in American football or a four-point stance as in track.

c. Subject is given a countdown, either verbally or, if using timing gates, by using the beeps programmed into the timing gate unit or the electronic switched.

d. The subject should be allowed two or three trials unless subject continues to decrease speed time. Subject should receive three to five minutes of rest between sprints to ensure nearly full recovery.
e. If using a stop watch, start the watch at the end of count verbal countdown. Times are typically recorded to the nearest 0.01 second. Hand times can result in times that are faster than the times recorded using a timing gate. Thus, consistency in equipment from test to test and with the same subject performing repeated measures.

HAND AND EYE COORDINATION: MODIFIED HAND WALL TOSS

A mark is placed a certain distance from the wall (e.g. 2 meters, 3 feet) plus added full extension arm length of subject distance from the 3 feet. The person stands behind the line and facing the wall.

a. Tester gives the command “GO” and starts the stopwatch

b. Subject throws ball from one hand (dominant) in an underarm action against the wall, and attempted to be caught with the opposite hand. The ball is then thrown back against the wall and caught with the initial hand.

c. Cycle of throwing and catching is repeated for 30 seconds

Tester counts the number of catches and stops the test after 30 seconds. Number of catches is recorded. By adding the constraint of a set time period, you also add the factor of working under pressure.

BALANCE AND STABILITY: MODIFIED BASS TEST

Subject jumps from square to square, in a numbered sequence, using only one leg. Hands should remain on the hips.
b. On landing, subject remains looking facing straight ahead, without moving the support leg, for five seconds before jumping to the next square.

c. Tester should count aloud the five seconds the subject is to maintain the position before moving to the next square.

There are two types of errors:

1. Landing errors- occurs if the subject’s foot does not cover the tape, if the foot is not facing forward, if subject stumbles on landing, or if subject takes the hands off hips.

2. Balance errors- occurs if the subject takes the hands off the hips or if the non-testing leg touches down, touches the opposite leg, or moves into excessive flexion, extension, or abduction. Subject may look at the next square before jumping to it.

At the conclusion of the test, 10 points are given for each five-second period in which there was a landing error and 3 points for each period in which there was a balance error. The sum of the two is the total score. At least two practice sessions should be given before testing for score.

**LOWER BODY STRENGTH: 1RM BACK SQUAT**

Subject will warm up by completing 5-10 repetitions of a sub-maximal weight followed by one-minute rest. Subject will then be asked to perform single repetition efforts with each single effort you will be asked to lift slightly more weight. An estimated warm-up load that allows subject to complete 3-5 repetitions by adding 30-40 pounds (14-18kg), or 10-20%, to the load used previously is added followed by two-minute rest.
Estimate a near maximal load that allows subject to complete 2-3 repetitions by adding 30-40 pounds (14-18kg), or 10-20%, to the load previously used followed by two- to four-minute rest. Subject then performs a 1RM attempt by increasing the load used in step e by 30-40 pounds (14-18kg), or 10-20% followed by two- to four-minute rest. If subject fails 1RM attempt, decrease the load by removing 15-20 pounds (7-9kg), or 5-10%, and the subject will perform one repetition followed by two- to four-minute rest. Continue increasing or decreasing the load until the subject can complete 1RM with appropriate technique. The subject’s 1RM will be achieved within 5 attempts.

**UPPER BODY STRENGTH: 1RM WEIGHTED CHIN UP**

. Subject will warm up by completing 5-10 repetitions of a sub-maximal weight.

b. One-minute rest

c. Subject will then be asked to perform single repetition efforts with each single effort you will be asked to lift slightly more weight. Estimate a warm-up load that allows subject to complete 3-5 repetitions by adding 10-20 pounds (4.5-9kg), or 5-10%, to the load used in step a.

d. Two-minute rest.

e. Estimate a near maximal load that allows subject to complete 2-3 repetitions by adding 10-20 pounds (4.5-9kg), or 5-10%, to the load used in step c.

f. Two- to four-minute rest.
g. Subject performs a 1RM attempt by increasing the load used in step e by 10-20 pounds (4.5-9kg), or 5-10%.

h. Two- to four-minute rest.

i. If subject fails 1RM attempt, decrease the load by removing 5-10 pounds (2.3-4.5kg), or 2.5-5%, and have the subject perform one repetition.

j. Two- to four-minute rest.

k. Continue increasing or decreasing the load until the subject can complete 1RM with appropriate technique. The subject’s 1RM should be achieved within 5 attempts.

UPPER BODY ENDURANCE: PULL UP TEST

Subject begins by hanging from the bar with arms straight and an underhand grip (supinated) about shoulder width apart.

b. Subject pulls the body upward until the chin is above the bar.

c. The subject returns to starting position.

d. Any swinging movements during the exercise should be avoided. The number of repetitions before volitional failure should be recorded.