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PHYSIOLOGICAL PROFILE OF MIXED MARTIAL ARTISTS

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Abstract

Background and aim: Mixed martial arts (MMA) is a combat sport composed of traditional combat sports. The purpose of this study was to compare the physiological characteristics of amateur MMA fighters with other combat sports.

Material and methods: Eleven male MMA fighters (age 25.5 ± 5.7y, height 174.8 ± 5.3cm, body mass 77.4 ± 11.4kg) were measured for body composition, vertical jump, flexibility, grip strength, maximal oxygen consumption ($\dot{V}O_2$max), and relative one repetition-maximum bench press and squat.

Results indicated that MMA fighters had similar body fat percentage (11.7 ± 4.0%) to judokas (11.4 ± 8.4%), but greater than wrestlers (7.6 ± 3.4%) and kung fu (9.5 ± 6.3%). Their $\dot{V}O_2$max (55.5 ± 7.3 ml/kg/min) was comparable to wrestlers (54.6 ± 2.0 ml/kg/min), but greater than judokas (48.3 ± 8.1 ml/kg/min) and less than kickboxers (62.7 ± 3.6 ml/kg/min). MMA fighters were less flexible (30.3 ± 10.6 cm) than kung fu athletes (45.5 ± 6.1 cm) but were as flexible as wrestlers (30.8 ± 5.8 cm). MMA fighters (57.6 ± 7.3 cm) had less vertical jump than wrestlers (60.0 ± 10.0 cm), both of whom were greater than kung fu (45.5 ± 6.1 cm). MMA fighters had similar relative bench press (1.2 ± 0.1 kg/kg) and relative squat (1.4 ± 0.1 kg/kg) compared to judokas (bench press 1.2 ± 0.1 kg/kg and squat 1.4 ± 0.1 kg/kg). Boxers had greater right grip strength (58.2 ± 6.9 kg) than MMA fighters (45.8 ± 6.2 kg).

Conclusion: In conclusion, amateur MMA fighters have a physiological profile similar to judokas and wrestlers.

***Key words**: characteristics, fighters, amateur, combat*

Introduction

In 1993 the Ultimate Fighting Championship (UFC) introduced Mixed Martial Arts (MMA) to a mainstream audience. Since its primitive beginnings, MMA has been steadily gaining popularity and is now an internationally recognized sport. Recent UFC broadcasts have drawn in an average of 1.5 million viewers while generating more revenue than any other pay-per-view event. There were over 900 MMA training centers in North America in 2006 [1]. High television ratings and the increasing volume of training academies exemplify the growth of MMA's popularity. This study is the first that provides detail into the physiological characteristics of an amateur participant, and how he compares to his more specialized counterparts.

Early MMA fighters specialized in their art and did not train in other combat sports. Today, MMA fighters train in a multitude of combat sports, usually specializing in the art that is most suited for their body type [2]. Although some sports are similar in nature, athletes' physical properties can be significantly different. Iwai et al. [3] investigated the sport specific characteristics of trunk muscles in collegiate wrestlers and judokas and found that absolute and relative trunk extensor and flexor peak torque, work, and average torque were greater in wrestlers than judokas. Even for similar activities, sport specific training methods are necessary to develop proper proficiency in the sport [4].

Along with the necessary physical attributes of strength, power, and endurance, technical proficiency is a vital aspect of being a successful MMA fighter. Athletes with less experience, and therefore less technical skills, have a greater risk of injury [5]. In addition to having more technical knowledge, elite athletes have less body fat than their amateur counterparts [6, 7]. Greater body fat percentage is negatively correlated with performance in activities involving body mass locomotion [8-10]. Franchini et al. [8] conducted a study to determine the physical fitness and anthropometric profile of the Brazilian male judo team. Results of the study determined that the physical variables measured did not discriminate performance when analysis was directed to the best athletes [8], therefore emphasizing the importance of technical proficiency.

Profiling can be a valuable means of identifying talent, strengths, and weaknesses, and helping in the design of optimal strength and conditioning programs [11]. Physiological testing can assess the overall fitness level of the athletes and set guidelines for individualized MMA training programs. Therefore, the purpose of this study was to describe the physical characteristics of amateur mixed martial artists with comparison to other combat sports.

Materials and methods

Experimental Approach to the Problem

To investigate the physiological profile of mixed martial artists, we utilized a battery of fitness tests com-

posed of two testing sessions. One session consisted of anthropometric measurements, body composition, grip strength, sit and reach, vertical jump, and 1RM squat. The second session consisted of 1RM bench press and a $\dot{V}O_2$max test. The results were compared to other combat athletes from previous literature. Athletes were deemed similar if values were within ±3% of MMA figures.

Subjects

Eleven male MMA fighters (age 25.5 ± 5.7y, height 174.8 ± 5.3 cm, body mass 77.4 ± 11.4 kg) volunteered for this study. The subjects participated upon Institutional Review Board approval after reading and signing the informed consent. Subjects were required to be active mixed martial artists who trained a minimum of two times a week. They must have had a minimum of two years competitive fighting experience and were required to have no history of cardiovascular disease. Subjects had both regional and local fighting experience in amateur competitions. Subjects participated in regular weight training for a minimum of two times per week for at least one year, and were adept at performing a bench press and squat. Performance would not have been improved with a familiarization session due to the subjects' previous strength training experience. Although participants did not regularly test their maximum jump height, learning effects were controlled by multiple attempts. A certified strength and conditioning specialist monitored every session.

Procedures

Testing took place on two visits. The first visit was an assessment session consisting of anthropometric measurements, grip strength, flexibility, vertical jump, and 1RM squat. Anthropometric measurements included height, body mass, and body composition. Height was measured using a stadiometer (SECA, Ontario, CA) and body mass by a Healthometer digital scale (Ohaus, Pine Brook, NJ, ES200L). For skinfold measurement, we utilized the Jackson and Pollock 7-site skinfold caliper test. The following sites were assessed: triceps, chest, midaxilliary, subscapular, suprailliac, abdominal, and thigh. All measurements were taken on the right side of the body. A Lange caliper (Beta Technology, Santa Cruz, CA) was placed 1-2cm away from the thumb and finger and perpendicular to the skinfold. When the value was displayed on the caliper, there was a 1- to 2-second hold until the lever was released. The value was rounded to the nearest 0.5mm. Three measures were taken at each site. If the score of the three assessments were not within 2mm, the average of the two closest were taken. Assessments were rotated through measurement sites to allow adipose tissue to decompress.

The second purpose of this session was to determine grip strength of the subjects. The Jamar handgrip dynamometer (Asimov Engineering Co., Los Angeles, CA, J00105) was adjusted to the hand size of the subject, where knuckles were parallel to the dynamometer. The subject held the device by the side and had three attempts for both the right and left hands. The subject first conducted the test on their right hand, followed by their left, and repeated. The best score of three attempts was recorded.

The third purpose of this session was to determine flexibility via sit-and-reach. Participants were asked to remove their shoes, place their feet flat against the sit and reach device (Novel Products Inc., Addison, IL), and lock their knees and legs straight against the measuring device. The subjects then stacked their hands on top of one another, inhaled and exhaled. While exhaling, the subject pushed the slider as far as possible. Results were void if the athlete did not maintain locked knees. The best of three trials was recorded.

The fourth purpose of this session was the vertical jump. An initial measurement was taken with the subject standing directly underneath the Vertec (SENOH, Columbus, OH) reaching as high as possible with his feet flat on the ground. The subjects held their arms straight out so that they were parallel to the ground then performed a countermovement jump with arm swing to touch the highest vane possible. Vertical jump was measured as jump height minus the subject's reach height. The best of three trials was recorded. The subject rested for 10 minutes following the vertical jump.

The last purpose of this session was to measure the subject's lower body strength via 1RM parallel squat using a protocol derived from Hoffman [12]. The subject performed a back squat with the bar settled below the C7 of the cervical spine. During the eccentric muscle action, the quadriceps were required to be parallel to the ground after the eccentric contraction phase for the repetition to be deemed successful. The assessment began with a warm-up of ten repetitions at 50% of the subject's estimated maximum. After a 2-minute rest period, the load was increased to 75% of the subject's estimated maximum by which the subject completed five repetitions. After a 3-minute rest, load was increased to attempt the 1RM lift. The load was increased by 10% increments after each successful lift by which the participant rested four minutes between attempts. If the lift was unsuccessful, the subject's 1RM was the last successful lift.

The second session commenced a minimum of 48 hours after the first session, with no physical activity 24 hours prior to testing. The first purpose of the second session was to measure the subject's 1RM bench press using a protocol derived from Hoffman [12]. The subject placed his head, shoulders, and hips on the bench and his feet were placed flat on the floor. The subject was eye level under the bar with a grip slightly wider than shoulder-width apart. For the repetition to be successful, the bar had to complete a full range of motion

Table 1. *Characteristics (mean ±SD) of male mixed martial artists with comparision to other combat sports*

Variables	MMA	JUDO	WRESTLING	BOXING	KUNG FU	KICKBOXING
Height (cm)	174.8 ± 5.3 171.2 – 178.4*	176.2 ± 8.9 167.9 – 184.4*				
Body mass (kg)	77.4 ± 11.4 69.7 – 85.2*	90.6 ± 23.8 68.6 – 112.6*				
Body Fat Percentage (%)	11.7 ± 4.0 9.0 – 14.4*	11.4 ± 8.4 3.6 – 19.1*	7.6 ± 3.4 4.6 – 10.5*		9.5 ± 6.3 5.0 – 13.9*	
Right Grip (kg)	45.8 ± 6.2 41.6 – 50.0*			58.2 ± 6.9 52.4 – 64.0*		
Left Grip (kg)	45.6 ± 5.9 41.6 – 49.6*					
Sit and Reach (cm)	30.3 ± 10.6 23.1 – 37.4*		30.8 ± 5.8 25.9 – 35.6*		45.5 ± 6.1 41.1 – 49.8*	
Vertical Jump (cm)	57.6 ± 7.3 52.7 – 62.5*		60.0 ± 10.0 51.6 – 68.3*		37.7 ± 8.4 31.6 – 43.7*	
IRM Relative Bench Press (kg/kg)	1.2 ± 0.1 1.1 – 1.3*	1.2 ± 0.1 1.1 – 1.3*				
IRM Relative Squat (kg/kg)	1.4 ± 0.1 1.3 – 1.4*	1.4 ± 0.1 1.3 – 1.4*				
$\dot{V}O_2$max (ml/kg/min)	55.5 ± 7.3 50.6 - 60.4*	48.3 ± 8.1 40.8 – 55.7*	54.6 ± 2.0 52.9 – 56.2*			62.7 ± 3.6 56.9 – 68.4*

* 95% Confidence Intervals

by contacting the chest and terminating with elbows fully extended. The repetition was deemed unsuccessful if hips lost contact with the bench. The assessment began with a warm-up of 10 repetitions at 50% of the subject's estimated maximum. After a 2-minute rest period, the load was increased to 75% of the subject's estimated maximum by which the subject completed five repetitions. After the load was increased to attempt the 1RM lift, the subject rested for four minutes between attempts. The load was increased by 10% increments after each successful lift. If the lift was unsuccessful, the subject's 1RM was the last successful lift.

The last purpose of the second session was to determine the participant's aerobic endurance. Subjects completed a 5-minute warm up on a Monark cycle (Monark, Sweden, Ergomedic 839E) prior to beginning the test. Subjects completed a $\dot{V}O_2$max test on a Trackmaster treadmill (JAS fitness Systems, Carrollton, TX, TM500-S) utilizing Gerkin protocol (12). The TRUEMAX 2400 metabolic cart (PARVOMEDICS, Sandy, UT) analyzed $\dot{V}O_2$.

Blood pressure was taken and a heart rate monitor (Polar, Kempele, Finland, FS1) was attached to record heart rate. During the test, the subject wore a nose clip and headgear that held a rubber mouthpiece so exhaled air was collected. The protocol consisted of walking on the treadmill at 3.0 miles per hour for 2-minute stages that increased in speed by 0.5 miles per hour. Subjects were encouraged to exercise as long as they could. If at any point subjects felt any signs of intolerance (light headedness, dizziness, chest pain, irregular heartbeat, etc.) they were encouraged to stop. The MMA fighter was considered to have reached their $\dot{V}O_2$max if any of these factors occurred: plateau of oxygen uptake, maximal heart rate was reached, respiratory exchange ratio (RER) of 1.15 or greater, or volitional exhaustion. At the conclusion of the test, they continued to walk on the treadmill at a reduced intensity for a few minutes to allow heart rate to return to 120 bpm or below. They then recovered in a seated position until heart rate returned below 100 bpm and subjects felt recovered.

Statistical Analyses

Descriptive statistics were obtained using SPSS 17.0 software (SPSS Inc. Chicago, IL). Data were compared and contrasted to combat athletes from various other sports using confidence intervals (95% CI).

Results

MMA fighters had similar body fat percentage to judokas, but greater than wrestlers and kung fu. Their $\dot{V}O_2$max was comparable wrestlers, but less than kickboxers and greater than judokas. MMA fighters were less flexible than kung fu athletes but were as flexible as wrestlers. MMA fighters had less vertical jump than wrestlers but greater than kung fu. MMA

fighters had similar relative bench press and relative squat compared to judokas. Boxers had greater right grip strength than MMA fighters. (Table 1).

Discussion

Mixed martial arts is a unique sport that attracts athletes from a wide array of combat backgrounds. Nevertheless, these athletes encompass a large range of body types, from ectomorphic kickboxers to mesomorphic wrestlers [13, 14]. Physical fitness tests may provide both the MMA fighter and coach with information relative to the athlete's physiologic capability. This information may allow them to perform a comparison with reference values of their peer group. By assessing the current fitness levels of MMA fighters, an optimal training program may also be developed to address their strengths and weaknesses.

Franchini et al. [8] found that a higher percent body fat is negatively correlated with performance in activities with body mass locomotion. Successful performance in activities that require the application of force against external objects is positively related to the amount of absolute fat free mass and body size. Amateur MMA fighters in our study had a body fat percentage of 11.7 ± 4.0%, which is similar to the Brazilian National judo team (11.4 ± 8.4%) [8] but greater than the U.S. National wrestling team (7.6 ± 3.4%) [15]. Although MMA fighters in this study had considerably lower body fat compared to normal men in their age group [12], they had greater levels compared to wrestlers due to fewer competitions and therefore a less restrictive diet. Subjects utilized in the present study did not train on a national team of any kind, which would require multiple training sessions per day.

Aerobic capacity has been well recognized as an important physiological contributor to performance [16, 17]. Our MMA fighters' $\dot{V}O_2$max was 55.5 ± 7.3 ml/kg/min, which was comparable to reports of judokas, kickboxers, and wrestlers [8, 14, 15]. In a study of the U.S. National Judo team, average values were 53.2 ± 1.4 ml/kg/min [18] while the Brazilian National Judo team had average values of 48.3 ± 8.1 ml/kg/min [8] and the U.S. National Wrestling team had values of 54.6 ± 2.0 ml/kg/min [15]. Kickboxing had the greatest $\dot{V}O_2$max at 62.7 ± 3.6 ml/kg/min [14]. American kickboxing is similar to boxing in that bouts are usually 3 to 12 rounds lasting 2 to 3 minutes each, with 1-minute rest between rounds [14]. The total duration of a kickboxing match may be 36 minutes, while MMA bouts are usually less than 15. There is a greater emphasis on aerobic training in kickboxing compared to wrestling, judo, and MMA, all of which have a large anaerobic component. With a $\dot{V}O_2$max of 55.5 ± 7.3 ml/kg/min, amateur MMA fighters have comparable figures to wrestlers [15]. The MMA fighters' numbers are especially high when taking their amateur status into account, as they were compared to elite level athletes. The high average $\dot{V}O_2$max values the MMA fighters exhibited when compared to normal men's average of 42.5 ml/kg/min [12] may be attributed to the intense cardiovascular conditioning workouts in which they participate. Mixed martial artists participate in both aerobic-based kickboxing and boxing classes along with anaerobic-based grappling courses.

Aerobic capacity is one of the most significant physical factors for success in wrestling [19]. MMA and wrestling are alike in that the fight can be strictly a wrestling match. In accordance with the metabolic specialization concept, superior aerobic capacity is often paired with inferior anaerobic capacity [16]. The Ultimate Fighting Championship utilizes three 5-minute rounds for non-championship bouts and five 5-minute rounds for championship fights [2]. Therefore, aerobic capacity cannot be ignored given the duration of each bout. Mixed martial arts is physically demanding for both cardiovascular and musculoskeletal systems [20] and a weak aerobic component may be a limiting factor in performance and should be developed to allow the athlete to perform at a high level throughout the fight.

The muscular strength values of MMA fighters in this study were similar to those reported in previous research on judokas. The MMA values in the squat and bench press are equivalent to those reported by Franchini et al. [8] who studied the Brazilian National Judo team. MMA fighters and the Brazilian judo team both had a relative bench press (kg/kg of body mass) of 1.2 ± 0.1. In reference to lower body strength, mixed martial artists and judokas both had a relative squat (kg/kg of body mass) of 1.4 ± 0.1. The figures are analogous despite the different competitive levels of the two subject groups. Grip strength is also an important aspect of MMA because they must be able to successfully control their opponent on the ground. In a study assessing amateur boxers, right hand grip strength was reported as 58.2 ± 6.9 kg [21]. This value is much greater than the MMA fighters' score of 45.8 ± 6.2 kg. This difference may be due to a heavier emphasis placed on upper body development in boxing than in MMA. Boxers frequently develop forearm and wrist strength through training methods utilizing the heavy bag and speed bag. As a function of repetitive impact against opponents and bags, forearm and wrist musculature adapts and develops accordingly [22, 23]. In contrast, amateur MMA fighters do not train with those tools as consistently as boxers. Brazilian jujitsu may require the use of gis (kimono-style garment constructed with thick cotton) to emphasize technique and develop grip strength, but the majority of our subjects did not train in gi. Mixed martial artists were similar to

judokas in regards to upper and lower body strength, but had notably less grip strength than boxers.

Mixed martial arts encompass both repeated explosive movements and submaximal dynamic work. Power is an important aspect of MMA because of its quick movements and extensive utilization of the ATP-PCr energy system. According to Carter et al. [7], Olympic level wrestlers perform a mean of 16 high-intensity sequences with each attack lasting 3.1 seconds. The athletes then recover for approximately 23 seconds. MMA is also characterized by high-intensity intermittent exercise, thereby making anaerobic power crucial. Vertical jump is a simple measure to estimate lower body power. MMA fighters in this study jumped a mean of 57.6 ± 7.3 cm. A study of the U.S. National wrestling team found their athletes jumped 60.0 ± 10.0 cm [15]. The slight difference in vertical jump performance may be attributed to wrestling's greater anaerobic demands, compared to the diverse nature of MMA. MMA does not require the same degree of lower body power to execute takedowns as wrestling.

Despite the fact that there is inadequate research to support that flexibility improves performance and reduces injuries, limited flexibility may be a serious disadvantage in MMA where limbs may be forced through the full range of motion. MMA fighters in this study had a mean sit and reach value of 30.3 ± 10.6 cm. This is similar to figures reported by Callan et al. [15] on freestyle wrestlers (30.8 ± 5.8 cm) but much less than elite kung fu athletes (45.5 ± 6.1 cm) [24]. Traditional martial arts such as tai kwon do and kung fu focus on flexibility training to a large extent and incorporate it into training sessions on a regular basis. MMA and wrestling do not focus on flexibility to the same degree as kung fu, and typically leave that as an optional phase of training.

MMA fighters shared similar body composition to judokas but greater than wrestlers and kung fu. They had comparable trunk flexibility to wrestlers but had less maximum vertical jump. MMA fighter's $\dot{V}O_2$max was similar to wrestlers. In relation to strength, MMA fighters had corresponding relative bench press and relative squat values compared to judokas. Our study provides baseline values for future investigations where physiological fitness status may be utilized to create strength training programs to prepare MMA fighters for the physical demands of their sport.

Conclusion

In conclusion, the fitness profile results of amateur MMA fighters demonstrated that they exhibit similar fitness characteristics to elite judokas and wrestlers. However, MMA fighters had average grip strength and trunk flexibility [12]. Therefore, MMA athletes should incorporate gi training during grappling practice and add grip-strengthening exercises to their strength training routine. MMA fighters may also benefit from flexibility training after practice.

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A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection