ORIGINAL ARTICLE

Anthropometric profile and physiological performance of Colombian elite mixed martial arts athletes

Cristian Andres Yánez . *Sports Science Program. Faculty of Health Sciences. University of Applied and Environmental Sciences, UDCA. Colombia.*
Fitness Academy. Colombia.
Nestor Ochoa. *Sports Science Program. Faculty of Health Sciences. University of Applied and Environmental Sciences, UDCA. Colombia.*
Paola Bocanegra. *Colombian School of Rehabilitation. Colombia.*
Adriana Beltran. *Health Services Provider Institution. Kinefit: Medical and Health. Colombia.*
Julio Angulo. *Cucuta Deportivo. University of Santander. Colombia.*
Karol Arevalo. *Fitness Academy. Colombia.*

ABSTRACT

It is essential to describe performance profiles and implement training loads for MMA athletes participating in competitions, as well as to explore and develop new training models as a priority for MMA coaches. The objective of this study was to evaluate the anthropometric characteristics and physical performance of contemporary elite male mixed martial arts (MMA) athletes. Professional Colombian Mixed Martial Artists were assessed before participating in the sport combat championship (Mean age = 30.80 ± 4.56 years, height = 174.00 ± 3.43 cm, weight = 77.97 ± 8.84 Kg). Athletes underwent evaluations on body composition and sports performance parameters including bioelectric impedance analysis (BIA), VO_{2max}, maximal aerobic speed (MAS) and handgrip strength and other variables. The evaluations revealed a mean muscle mass of 64.67% ± 5.20% (95% CI, 67.89%-61.44%), body fat percentage of 10.93% ± 4.31% (95% CI, 13.60%-8.25%), Ponderal index of 14.79 ± 1.50 (95% CI, 15.72-13.86) and bone mass 3.45 ± 0.27 (95% CI, 3.61-3.28). Mean VO_{2max} was 63.23 ± 5.50 ml/min-1/Kg-1 (95% CI, 66.64-59.81). This information can assist in assessing and evaluating sports performance as well as in developing and optimizing specific training regimes and identifying talents.
Keywords: Performance analysis, MMA, Strike fighting style, Combat sports.

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Corresponding author. *Sports Science Program. Faculty of Health Sciences. Fitness Academy. University of Applied and Environmental Sciences, UDCA. Colombia.*
E-mail: criyan2022@gmail.com
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INTRODUCTION

MMA encompasses various martial arts that incorporate both striking and grappling techniques, such as Brazilian jiu-jitsu (BJJ), kickboxing, wrestling, Muay Thai, and other styles (Coswig et al., 2016; Matinlauri et al., 2019) these styles involve short-term high-intensity and explosive actions, emphasizing the importance of glycolytic pathways during fights (James, Robertson, et al., 2017; Schick et al., 2010). The term "*pan*," meaning all, and "*kratos*", meaning power together define mixed martial arts (Amtmann & Berry, 2003). Additionally, the physiological demands primarily stem from the glycolytic and oxidative systems (Bishop et al., 2013; Powers S, 2021 p.54) justifying the change in MMA bout length to five rounds.

On the other hand, developing new sports conditioning models is crucial for MMA coaches (Kirk et al., 2021; Kostikiadis et al., 2018) to implement training loads based on exercise physiology, physical fitness tests, and sports monitoring (Tota et al., 2014), this should align with the demands and intensity of official MMA competitions, emphasizing the importance of contributing to the scientific community of sports science. As a result, sports assessments underscore the necessity of researching MMA athletes as the periodization of the training process vital for achieving high performance. Athlete characteristics inform talent identification, performance testing, and training strategies. Understanding, the relationship between competition and training can offer valuable insights into developing the optimal performance profile for MMA athletes.

Sports coaches must develop various factors to achieve high performance including physical, technical, and tactical characteristics). Therefore, knowledge of the physical demands is one of the most important aspects of competence (Kirk et al., 2021). Understanding these physical demands is crucial for improving physical training (e.g., endurance, speed, and strength), reducing the occurrence of neuromuscular fatigue, and decreasing the risk of injury (Štyriak et al., 2023).

Finally, it is all essential to understand the physiological and performance profiles of MMA athletes to properly program load plans specific to the sport. With this knowledge, coaches can design training programs tailored to the individual needs of players. Therefore, the primary purpose of this study was to examine the physical and physiological characteristics of MMA athletes.

MATERIALS AND METHODS

Participants

A total of 10 mixed martial arts (MMA) athletes from Bogotá, Colombia (ranked as "*Tapology*" Professionals Colombian Mixed Martial Artists) who have been active in MMA competition within the last two years and have over 10 years of experience in elite competition between 2010 and 2023, volunteered to participate in the study. Subjects signed declarations of informed consent. Participants were asked to complete a health history questionnaire and were accepted into the study if they had no contraindications such as osteomuscular injuries. This study has been approved by the Institutional Ethics Committee of the University of Applied and Environmental Sciences UDCA (Sports Science program with approval No.: 01/2025; and an approval date of 9 February 2025, following the latest update of the Declaration of Helsinki (2013).

Measures

All participants completed a ten-minute standardized warm-up before the jump test. The warmup included jogging, dynamic flexibility exercises, joint mobility exercises, and three counter movement jumps (CMJ) performed in increasing order of intensity. Subsequently, anthropometric measurements were assessed. A stadiometer (Seca Corp. Chino, CA, USA) was used for measuring height. A digital scale InBody 370 (InBody, Seoul, South Korea) was used to measure body mass, body fat, and average lean muscle weight. Body mass index BMI was calculated as body mass in kilograms divided by height in meters squared (kg/m2). Neuromuscular performance measurement was performed for all athletes, who each completed three standardized countermovement jumps (CMJ).

Procedures

VO_{2max} cardiovascular test

Participants completed a maximal graded exercise test on a treadmill (Reims) calibrated monthly for accuracy of grade and speed. The maximal graded exercise test protocol began with a warm-up at a self-selected pace (3 mile/h = 4.9 km/h) on a treadmill for 7 to 15 minutes. During the warm-up, the research staff explained on how to use the Borg Rating of Perceived Exertion (Borg, 1982) scale and informed athletes that they were expected to achieve the maximum level of exertion. The participants were then equipped with a Bluetooth-enabled heart rate monitor worn on the chest (Polar). The preprogrammed treadmill protocol started with participants running at 3.1 mph (5 km/h) for 5 minutes (with a 0% incline). The workload was then increased by 1.0 mile/h = 1.6 Km/h, total: 6.4 Km/h). This was achieved via an enlarge in speed (1.0 mph per minute, 1.6km/h) each minute until the athlete until a maximal speed was reached. If a participant's capacity allowed them to continue beyond neuromuscular fatigue, the treadmill´s grade (i.e., incline) remained constant, but the speed increased, until volitional fatigue was reached. The protocol continued until the participant signalled to stop. The Borg Rating of Perceived Exertion scale was assessed during the final 10 seconds of each minute. Additionally, participants completed an incremental protocol to determine their maximal aerobic speed (MAS) (Bueno et al., 2022; Chaabène et al., 2015). Upon reaching volitional fatigue, participants were encouraged to walk until fully recovered while the treadmill was immediately slowed to 1.5 mph. Finally, maximal VO_2 (ml min−1 kg−1) was calculated using the ACSM treadmill running equation (equation 1) for the last stage of the running test (Deborah Riebe, 2016 pp.156).

Equation 1 $$VO_{2max}\ (\text{ml min}^{-1}\ \text{kg}^{-1}) = S * 0.20 + 3.5$$

S = speed (meters/min)

Handgrip Strength (HGS)

For each assessment, two maximal efforts of 5 seconds were performed with both the dominant and non-dominant hand, with a 1-minute rest between efforts. A hand dynamometer was held with the elbows at the side of the body and the arm at right angles. Grip strength was assessed using a hand dynamometer (Hand dynamometer, Camry Instrument Company, China). Grip strength assessment has been used in previous research on combat sports and was therefore chosen for this study (Constantine et al., 2019; Coswig et al., 2016). The instrument was adjusted so that its base rested on the first metacarpal and the handle rested on the middle of the participant's four fingers. A maximal isometric effort was sustained for 5 seconds, without any additional body movements. The trial with the highest force was selected for analysis.

Squat and countermovement jump

Squat jump (SJ) and countermovement jump (CMJ) trials were conducted on a calibrated force plate (Kinvent, Montpellier, France) to evaluate force-generating capacity which is considered a reliable and valid measure of this capacity (Anicic et al., 2023; Bosco et al., 1983). Subjects performed a total of three attempts with the best trial being used for data analysis based on jump height. The squat jump (SJ) was performed following the protocol outlined by Van Hooren et al. (Van Hooren & Zolotarjova, 2017). Athletes were instructed to assume a semi-squat position and hold it for 3 seconds until the evaluator said "*START!*". Each player was directed to begin the test with a knee flexion (90°). Countermovement or any pre-stretching was not allowed before the acceleration (concentric) phase, and during the test, to prevent the use of upper limbs; arms had to remain on the pelvis. The jump had to be repeated if any of these characteristics were violated.

The countermovement jump (CMJ) was carried out similarly to the SJ, performing an explosive, fast countermovement without maintaining a knee flexion position (F. Ayala a, 2012; Folhes et al., 2022; Franchini, 2023). Participants were instructed to execute a quick downward movement (approximately 90° of knee flexion) followed by a fast upward movement to achieve maximum jump height. This jump tested the elastic properties of the players muscle-tendon structure and their concentric strength.

Isometric Midthigh Pull (IMTP)
This test can be used to assess various measures, including maximal strength. Participants were positioned in the IMTP rack, in a barbell position corresponding to the second pull of the clean, with hip- and knee angles of 140-145^{o} respectively (Beckham et al., 2018). The IMTP was selected for this study as it is considered the gold standard in strength testing (Haff G., 2019; James, Beckman, et al., 2017). Each athlete was instructed to assume their preferred second pull power-clean position by self-selecting the hip and knee angles. The barbell height was then adjusted up or down to ensure it was placed at mid-thigh level. All participants were strapped to the barbell and used an overhand grip. Athletes were instructed to pull the barbell as hard and fast as possible and to maintain maximal effort for 5 seconds. They were asked to relax before the command countdown of "*3, 2, 1, Pull!*" and received strong verbal encouragement throughout to ensure maximal effort. The force-time curve for each trial was recorded by a dual force plate (Kinvent, Montpellier, France) with a sample rate of 1,000 Hz.

Chin up (pull up) test
To be considered a complete pull-up, the subject was reported to lift his body from a full-arm extension hanging position (width-pronated grip) until his chin was above the bar. The pull-ups were performed on a standard, horizontal bar. The athletes were asked to complete the maximum number of free-hanging pull-ups with a pause of 1 to 2 s between repetitions (Kotarsky et al., 2018; Sanchez-Moreno et al., 2016). Half-repetitions were counted if the subject reached 90 degrees of elbow flexion. All participants completed an identical 15-minute warm-up, including arm and shoulder movements, and 3 submaximal sets of pull-ups.

V-sit and reach (VSR)
The legs were stabilized in an extended position by a researcher and two assistants. The participant was instructed to sit on the floor with the legs extended, the feet spaced 30 cm apart, and to keep the ankle joints in a neutral position. To perform the VSR, the athletes lined up one hand over the other, reached towards their toes until discomfort, and flexed at the waist. The action was performed three times, and the measurement was taken on the third attempt; the athletes were required to hold the position while the measurement was obtained (Guidetti et al., 2002; Haff, G., 2019). The researcher reviewed and measured from the edge of the baseline "*zero*" (located at the floor) line to the tip of the middle finger. A measurement of "*0*" indicated the fingertip was in line with the edge of the baseline "*zero*" tape line. Measurements were registered to the nearest half-centimetre. If the fingers had not reached the edge of the line, it indicated a negative number; if they had, it showed a positive number. The inability to obtain the "*zero*" line on the tape was defined a priori as a dysfunction on the VSR (Hansberger et al., 2019).

Mc Call test (hamstring strength tests)
For hamstring isometric strength testing, athletes were positioned supine with the heel of one leg on a cuff, knees flexed, and the opposite leg extended on the floor. The degree of knee flexion was determined by the distance of the hip from a chair and measured with a goniometer. Athletes were located supine, with arms

crossed over their chest, the heel of one leg on the cuff, knees flexed, and the opposite leg extended for hamstring isometric strength testing. The distance from the hip to a chair was similarly measured to determine knee flexion using a goniometer. In this test, the knee is flexed at either 90° or 30° to primarily target the hamstrings (biceps femoris, semitendinosus, semimembranosus), and the peak force exerted is measured in a supine position with the heel of the testing leg placed on a raised force platform (Huebner et al., 2023; l Lovell et al., 2013; James, Beckman, et al., 2017).

Analysis

All data were analysed and conducted with JASP (version 0.18.3, University of Amsterdam, Netherlands). Significance was set at $p \leq .05$ a priori. Anthropometric and physiological performance characteristics were expressed as mean ± standard deviation (SD).

RESULTS

The anthropometric characteristics of the participants are presented in Table 1. The physical performance of the participants is presented in Table 2. McCall and Isometric mid-thigh pull tests in Table 3. The jump test performance of the participants is presented in Table 4.

DISCUSSION

The purpose of this study was to characterize the anthropometric profile and physiological performance of Colombian Elite Mixed Martial Artists (MMA) fighters. Understanding the characteristics of fighter athletes is essential to justify the need for information on the combat sport profile, given the growth of MMA.

Data on athletes' heights around 1.74 (cm) and weights around 77.97 (Kg) are consistent with values for MMA athletes found in previous studies (Schick et al., 2010; Spanias et al., 2019). In terms of physical fitness and performance, results show that MMA athletes vary in body fat percentage, ranging from 8.5 to 14.9 ± 7.2% and have a mesomorph body type (predominance) (6.4 ± 0.8) (Franchini, 2023; Marinho et al., 2016).

Other measures used to describe the morphological profile include the ponderal index (Berthelot et al., 2015; Bishop et al., 2013; James, Beckman, et al., 2017), muscle (64.67%), and bone mass (3,45 Kg). Therefore, muscle mass development and bone strength are crucial components for mixed martial arts athletes and most combat sports (Schick et al., 2010; Spanias et al., 2019; Tota et al., 2014).

On the other hand, MMA fights require high cardiovascular fitness (Del Vecchio & Franchini, 2013) due to their intermittent nature (3 to 5 rounds of 5 minutes each). Our results (63.23 ± 5.5 ml·kg-1 ·min-1/ MAS: 17.92 ± 1.65 km/hr) are concerning as the level of glycolytic fitness has been linked to fatigue resistance (Panissa et al., 2013) and a high fitness level is a key factor for success in fights (Bueno et al., 2022). The VO_{2max} values are higher than those found among MMA fighters in previous studies (Andrade et al., 2019; James et al., 2018; Spanias et al., 2019).

Upper-body muscular endurance in athletes was assessed using maximum repetition chin-up tests. Our results (mean 11.20 ± 4.59 reps) were similar to those presented by MMA fighters (De Oliveira et al., 2015; Franchini et al., 2015; Schick et al., 2010). However, the results fall short of values reported for boxers (Chaabène et al., 2015; Guidetti et al., 2002) and karate fighters (Franchini et al., 2018). Compared with Jiu-Jitsu athletes, results varied, ranging from higher (Lima et al., 2017) to lower (Andreato et al., 2017; Andreato & Branco, 2016) than those reported in the literature.

Table 1. Anthropometric characteristics of elite male mixed martial arts (MMA) Athletes descriptive outcomes.

	Height (cm)	Age (years)	Weight (kg)	PI*	Fat (%)	Muscle (%)	Bone (kg)
Mean	174.000	30.800	77.970	14.792	10.930	64.670	3.450
95% CI Mean Upper	176.127	33.630	83.452	15.721	13.602	67.895	3.618
95% CI Mean Lower	171.873	27.970	72.488	13.863	8.258	61.445	3.282
Std. Deviation	3.432	4.566	8.846	1.500	4.310	5.203	0.272

*Note. *PI (Ponderal index) = weight (kg)/ height³ (m).*

Table 2. Physical performance characteristics of elite male mixed martial arts (MMA) athletes.

	VO_{2Max} (ml min−1 kg−1)	MAS (Km/h)	Chin up test rep	V sit and reach	Handgrip strength R	Handgrip strength L
Mean	63.233	17.920	11.200	4.767	47.055	47.470
95% CI Mean Upper	66.647	18.944	14.045	9.917	51.296	51.902
95% CI Mean Lower	59.818	16.896	8.355	-0.384	42.814	43.038
Std. Deviation	5.509	1.652	4.590	8.310	6.842	7.151
Minimum	56.832	16.000	4.000	-9.000	39.250	37.900
Maximum	72.832	20.800	18.000	17.667	56.400	59.750

Note. MAS: Maximal aerobic speed. L: Left; R: Right.

Table 3. McCall and Isometric mid-thigh pull tests characteristics of elite male mixed martial arts (MMA) athletes.

	McCall test MF 90° (Kg) L	McCall test MF 90° (Kg) R	McCall test MF 30° (Kg) L	McCall test MF 30° (Kg) R	RFD (Kg/sg) 90° L	RFD (Kg/sg) 90° R	RFD (Kg/sg) 30° L	RFD (Kg/sg) 30° R	IMTP L (Kg)	IMTP R (Kg)	IMTP total (Kg)
Mean	19.824	18.078	19.804	18.956	3.242	3.210	3.248	4.091	106.110	109.600	215.690
95% CI Mean Upper	23.865	20.385	23.833	22.021	4.386	3.914	4.549	5.697	117.875	125.389	233.030
95% CI Mean Lower	15.782	15.770	15.774	15.892	2.098	2.506	1.947	2.485	94.345	93.811	198.350
Std. Deviation	6.520	3.723	6.502	4.944	1.846	1.136	2.099	2.591	18.981	25.475	27.978
Minimum	11.660	13.360	11.210	10.970	0.470	1.430	0.410	0.250	79.200	73.800	167.500
Maximum	31.400	26.310	29.400	27.400	5.410	5.160	6.630	9.290	140.000	159.400	257.500

Note. L: Left. R: Right. MF: Max force. RFD: Rate force development. IMTP: Isometric mid-thigh pull.

Table 4. Squat jump and countermovement jump characteristics of elite male mixed martial arts (MMA) athletes.

	SJ MF L (Kg)	SJ MF R (Kg)	Total	FT (sc)	JH (cm)	RFD (N/s)	CMJ MF L (Kg)	CMJ MF R (Kg)	Total	FT (sc)	JH (cm)	RFD (N/s)	Max Power (W)
Mean	79.65	83.32	162.98	0.490	29.80	2185.92	79.92	96.14	175.84	0.514	32.60	4247.04	3665.54
95% CI Mean Upper	87.26	91.80	178.75	0.513	32.59	2601.97	90.75	109.85	191.95	0.527	34.25	6059.14	3965.62
95% CI Mean Lower	72.03	74.83	147.20	0.467	27.00	1769.86	69.09	82.42	159.72	0.501	30.94	2434.93	3365.45
Std. Deviation	12.28	13.68	25.45	0.038	4.51	671.27	17.47	22.12	26.00	0.022	2.67	2923.71	484.16
Minimum	65.10	68.50	133.50	0.430	23.0	1238.90	40.90	75.90	146.30	0.490	30.00	1249.50	3078.70
Maximum	106.90	111.60	218.50	0.540	36.0	3179.10	104.30	137.80	219.20	0.560	39.00	10549.50	4495.30

Note. SJ: Squat Jump. MF: Max force. FT: Flight time. JH: Jump height. RFD: Rate force development. CMJ: Counter movement jump. L: Left; R: Right.

Flexibility has gained attention and importance in MMA training, particularly due to its association with improved skill execution and a broader range of motion. The flexibility of athletes assessed in the current study (4.76 ± 8.31 cm) was lower than that of taekwondo (Nikolaidis et al., 2016; Spanias et al., 2019), judo (Franchini et al., 2015), and MMA athletes.

The handgrip (HG) strength test (Boone, 2015) and the isometric middle-thigh pull (IMTP) (James, Beckman, et al., 2017; Plush et al., 2021) were used to evaluate athletes' isometric maximal strength. The HG isometric strength for the left hand was 47.47 ± 7.15 and for the right hand 47.05 ± 6.84. The HG values were related to values found in BJJ (I Lovell et al., 2013), boxing (Gatt et al., 2018), sambo (Trivic et al., 2020), judo (Turnes et al., 2022), kickboxing (Rydzik & Ambroży, 2021), and wrestling athletes (Cieśliński et al., 2021; Huebner et al., 2023). The IMTP was measured via a Kinvent force plate (Plakoutsis et al., 2023). The absolute values ranged from 215.69 ± 27.97 (kg) and established a profile of high muscle strength for athletes in martial arts.

The isometric posterior chain (hamstring) of MMA athletes was evaluated. Using a force plate (Kinvent, Montpellier, France) to estimate the isometric endurance of each lower limb (Matinlauri et al., 2019; McCall et al., 2015) The results for Max Force, Left 90°: were 19.82 ± 6.52 (Kg). and for Max Force Left 30°: were 19.80 ± 6.50 (Kg). The RFD Left 90° (Kg/sg): was 3.24 ± 1.84. RFD Left 30° (Kg/sg): 3.24 ± 2.09. For the right-side Max Force right 90°: was 18.07 ± 3.72 (Kg). and at 30°: was 18.95 ± 4.94 (Kg). The RFD for Right 90°: was 3.21 ± 1.13(Kg/sg) and for Right 30°: was 4.09 ± 2.59(Kg/sg).

Our results show that the values for SJ (FT 0.49 ± 0.03, JH 29.80 ± 4.51, RFD 2,185 ± 671.2 (N/s), are lower compared to other studies on MMA fighters. However, the values for CMJ (FT 0.51 ± 0.02, JH 32.60 ± 2.67, RFD 4,247 ± 2,923 (N/s), Max Power (W) 3,665 ± 484.169 (Kostikiadis et al., 2018), are higher than those reported in previous studies. The higher values in our study may be attributed to the different sports demands of the subjects who are currently undergoing training to increase their rate of force development and peak concentric forces (James et al., 2020).

CONCLUSIONS

This study showed MMA fighters demonstrate satisfactory performance characteristics. Additionally, this study suggests that athletes have higher VO_{2max} values compared to athletes in other sports. Flexibility scores are low, which could impact performance, highlighting the importance of focusing on this motor skill. On the other hand, handgrip strength was higher than that of athletes in different combat sports. These findings offer insight into the profiles of elite Colombian MMA athletes and allow for comparisons with international data. These neuromuscular and physiological variables serve as valuable reference points for identifying sports talent, enhancing training skills, and achieving high performance.

Some limitations of this study included a small sample size of the athletes. Future research should take into consideration these limitations and strive to expand the scope of data collection. This should involve incorporating diverse assessment parameters, longer time periods, and a range of MMA categories.

AUTHOR CONTRIBUTIONS

Conceptualization, CY. and P.B.; methodology, N.O. and A.B.; data curation, C.Y, J.A. and N.O.; writing - original draft preparation, C.Y. and N.O.; writing -review and editing, K.A., J.A. and P.B.; supervision, N.O.;

project administration, C.Y. and A.B. All authors have read and agreed to the published version of the manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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