Physiological responses and physical performance of advanced and novice athletes in a specific MMA test

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ABSTRACT

In Mixed Martial Arts (MMA), the evaluation of athletes' performance is carried out mostly through non-specific tests. So far, there is only one specific test, the Anaerobic Specific Assessment for Mixed Martial Arts (ASA_{MMA}). Thus, the objective of the present study was to apply ASA_{MMA} to MMA athletes and compare their performance according to the competitive level. In the present study, 20 MMA athletes were involved, 10 advanced (ADV: 33.80± 4.80 years; height 179.40± 9.31 cm and 88.50± 20.83 kg) and 10 novices (NOV: 34.50± 5.81 years; 174.90± 5.99 cm and 86.00± 10.68 kg). In the first experimental session, anthropometric, resting heart rate (HR) and lactate (LA) measurements were performed. In the second session, ASA_{MMA} was applied. Due to the physiological demand of the evaluation, ADV athletes performed three rounds, and the NOV only performed one round. At the end of each round, the following were recorded: i) HR values, ii) blood LA concentration, iii) total number of sequences performed per round and iv) fatigue index in ASA_{MMA}. Regarding mean HR, differences were observed between groups (ADV: 167± 7.27 bpm and 89.2± 11.9% of maximum HR; NOV: 179± 3.8 bpm and 96.3± 3, 7% of maximum HR; $p< 0.001$). After the first round, LA concentration was 15.08± 2.86 mmol/L in ADV and 17.15± 1.36 mmol/L in NOV ($p= 0.054$). Among ADV, the LA increased throughout the rounds ($F_{(2,10)}= 5.81$; $p= 0.0111$; $\eta^2= 0.39$). ADV athletes performed a higher number of sequences in the first round (71.8± 7.87 versus 65.6± 2.87 repetitions; $p= 0.003$). However, in the analysis of repeated measures, a reduction in the number of sequences was observed throughout the rounds ($F_{(2,10)}= 14.37$; $p< 0.001$). Negative correlations were found between body fat percentage and ASA_{MMA} performance ($p< 0.05$) and between mean HR and ASA_{MMA} performance ($p< 0.01$). ASA_{MMA} can discriminate between advanced and novice athletes, both from a physiological (using heart rate as an indicator) and physical point of view, based on the number of sequences of movements.

KEYWORDS: martial arts; psychophysiology; sports; exercise; athletic performance.

INTRODUCTION

The combat sport named mixed martial arts (MMA) began in the third decade of the 20th century, when Carlos Gracie, one of the founders of "Gracie jiu-jitsu" (also known as Brazilian jiu-jitsu), invited competitors from different combat modalities to participate in the same event with few rules. MMA's fame has increased since 1993, with the first edition of the Ultimate Fighting Championship (UFC) in Denver, Colorado (Malanowski & Baima, 2021). Since then, MMA has become one of the fastest growing sports in the world. (Collier et al., 2011), gaining a lot of space in the media (Martin et al., 2015). However, this media advance was not accompanied at the same pace by the scientific support of the training and evaluation methodologies used by

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MMA athletes (Del Vecchio & Ferreira, 2013; Kirk et al., 2021). A systematic review of MMA was carried out by Bueno et al. (2022) highlighting a lack of studies focusing on technical-tactical aspects and physical fitness in MMA.

MMA requires intense physical effort from its practitioners, as it incorporates different techniques from different modalities, requiring many physical abilities and a need to train the technical, physical and tactical components in the same week (Bounty et al., 2011). This training density, when there is no properly structured planning, can lead to physical and psychological overload of the athlete (Kirk et al., 2021), may increase the risk of injury both during training periods and in competition (Ross et al., 2021). In this way, there is a need to increase scientific knowledge in planning MMA training in order to enhance the athlete's performance and reduce the risk of injury (Andrade et al., 2019), as well as looking for evaluation models that allow identifying the athlete's state of readiness for competitions (Chernozub et al., 2022).

The MMA athlete has peak oxygen consumption values (VO$_2$ peak) from 44.2± 6.7 mLO$_2$/kg/min to 55.5± 7.3 mLO$_2$/kg/min, estimated body fat percentage of 13,4± 5,6%, squat jump and countermovement jump of 51 cm and 45 cm (professionals and amateurs, respectively), long standing jump of 2.19± 0.31 cm, performs an average of 42 repetitions of sit-ups in 30s and 37± 9 repetitions of push-ups in the same duration, maintains an average of 35± 10s on the isometric pull on fixed bar and perform the bench press exercise, on average, with a load of 1.21± 0.18 kg per body mass for professionals and 1.07± 0.20 kg per body mass for amateurs (Andrade et al., 2019; Bueno et al., 2022). However, only the VO2 peak was obtained through a specific test of the MMA, with the remaining indicators of neuromuscular capacity being obtained through indirect tests not specific to the modality (Andrade et al., 2019; Bueno et al., 2022).

There are already validated tests measuring different physical abilities for combat sports, such as judo (Franchini et al., 2009), wrestling (Marković et al., 2021), jiu-jitsu (da Silva Junior et al., 2022), karate (Chaabène et al., 2012) and taekwondo (Tayech et al., 2019), being able, in the case of judo and jiu-jitsu, to differentiate the competitive level of the athletes (da Silva Junior et al., 2022; Franchini et al., 2009). In relation to MMA, until now, the evaluation of athletes' performance is carried out mostly through non-specific tests (Plush et al., 2021). As far as we know, there is only the test proposed by Paiva and Del Vecchio (2009) named Anaerobic Specific Assessment for Mixed Martial Arts (ASA$_{MMA}$).

The elaboration of the ASA$_{MMA}$ test was based on the duration of the MMA matches (3 to 5 rounds of five minutes, with a minute interval between them) and the analysis of the execution time of the different techniques used in the combat, conducted through the study of the MMA matches' dynamics (Del Vecchio et al., 2011). ASA$_{MMA}$ is associated with the aerobic capacity of $r= 0.87$ and $r= 0.60$ to aerobic power, both physical abilities measured in generic tests (Andrade et al., 2022). The ASA$_{MMA}$ result variation in amateur athletes between 3.1% and 4.3%. However, there are no studies showing if ASA$_{MMA}$ can distinguish different groups of athletes. Thus, the objective of the present study was to apply the ASA$_{MMA}$ in MMA athletes, and compare their performance according to the competitive level.

METHODS

Type of study and characterisation of variables

The present investigation presents an experimental design (Atkinson & Nevill, 2001). As independent variables, moment (rounds 1, 2 and 3) and competitive level (novice versus advanced) were considered. Physiological parameters (heart rate and blood lactate concentration) and ASA$_{MMA}$ performance parameters (number of strikes) were adopted as dependent variables.

Participants

Male MMA practitioners were involved, aged between 25 and 45 years old, with regular practice (3 times a week in the last 3 months). The sample size was determined using the G-Power software (version 3.1.9.7, Germany), using data from the study by Andrade et al. (2022) as a reference to estimate the required sample size. It was considered that the present study should contain two groups (advanced and novices), and a necessary sample of 10 individuals per group was calculated (5% alpha; 95% beta; statistical power≥ 0.95). Thus, 20 MMA athletes were intentionally recruited (*age*= 34± 5 years [95%CI 31.8–36.4]; height= 1.77± 0.07 m [95%CI 1.73–1.80]; body mass= 87.2± 16.2 kg [95%CI 80.2–94.3]; *BMI*= 27.6± 3.3 [95%CI 26.2–29.1]), all of them Brazilians residing in the United Arab Emirates in the period between January and October of 2022.

Procedures

After recruiting participants, visits to data collection sites were previously scheduled. Participants should be in a fed state (between 2 and 4 hours after the last meal), with a night's sleep of 8 hours or more and without high-intensity efforts on the day before data collection.

Two experimental sessions were required for the present study, separated by 24 to 48 hours. In the first session, the study procedures, and possible discomforts that participation could cause were presented. Clarification about the study design and data collection was allowed to the participants. Then, the participants who agreed to participate in the study read and signed an informed consent form. All procedures in this study followed the ethical precepts presented in the Declaration of Helsinki.

Still, in the first session, the participants completed a form with personal data and a standardised questionnaire on the level of competitive performance, in which the athletes are ranked, taking into account a scale from 1 (it represents that the athlete has not practised the sport for more 1 year) until 10, when the athlete has represented the country competitively in this sport (Manning & Pickup, 1998; Manning & Taylor, 2001). Based on the result of the questionnaire regarding competitive level, the participants were allocated into groups (Advanced= 8.5± 2.1 points; Novices= 2.6± 0.2 points; t= 12.24; p< 0.001). In the same session, height (SECA stadiometer, model 213, Deutschland, Germany, with 0.1 cm precision), body mass (EUFY scale, model C1, Changsha, China, with precision of 100 grams), and body fat percentage were measured. For this, a previously calibrated calliper was used (CESCORF®, Porto Alegre, Brazil), and the three-skinfold protocol — pectoral, abdomen and thigh — was used to estimate body density (Jackson & Pollock, 1978). Each skinfold was measured three times by a single evaluator and in a rotation system. After calculating the body density, the Siri equation was Applied to estimate body fat percentage (Siri, 1961).

Finally, in that same session, the participant was positioned in dorsal decubitus, and after 10 min of rest, the heart rate was measured for 5 min (Polar™ heart rate monitor, model H10, Kempele, Finland), and the average value of the period was considered (Schaffarczyk et al., 2022). Blood lactate was also measured at rest from a puncture in the digital pulp, with extraction of 0.8 µL and reading on portable equipment (Lactate Detect TD-4261 lactometer, EcoDiagnostica®, Nova Lima, Brazil).

In the second session, ASA$_{MMA}$ was applied. All participants were in the official uniform allowed for MMA events, consisting of shorts, 4 oz gloves and mouth guard, to increase specificity in relation to a real fight. Initially, the participants had 5 minutes to perform a targeted and modality-specific warm-up with self-selected movements of punches, kicks, dodges and displacements at light to moderate intensity. The evaluation procedure was performed in an environment with controlled temperature (25°C) and humidity (85%) in

a space with dimensions of 10 m x 10 m intended for the practice of martial arts, lined with 50 mm EVA™ rubberised plates.

The ASA$_{MMA}$ has a total duration of 1020 seconds (17 minutes), with 600 seconds of total motor actions distributed in 3 rounds with 420 seconds of pause (the pause time includes the interval between rounds). This duration of 600 s is distributed in 3 rounds, with 1 min rest between each. Each round consists of 3 blocks of efforts with specific MMA movements, which are repeated until the end of the total time for each round (movie: https://youtu.be/S7Sn7-ikNN4). Each effort block lasts 20 seconds and is performed at maximal intensity, followed by a 10-second active pause when the participant simulates low-intensity movements. Once the recovery is complete, the participant starts block 2 and so on (Figure 1).

Block 1: interaction

Lasting 20 seconds, the sequence jab/cross/semi-circle kick/sprawl is repeated until the end. For its realisation, a small rubberised training area of 10 m² is necessary, as well as the use of a punching bag for the movements of punches, kicks and sprawl (takedown defence).

Block 2: projection

With a duration of 20 seconds and with the help of a partner, projection movements (double leg) are performed. The training partner remains leaning against the wall, and the subject must remove the training partner from the same weight category from the ground without finishing the projection.

Block 3: ground & pound

A dummy or a punching bag on the ground is used to perform the movement known as Ground and Pound (punches and elbows on the ground level, with the subject evaluated on the dummy). In this block, jab, cross and elbow sequences are performed in the position known as "knee on the belly" for both sides, alternated after executing the three techniques sequentially.

These three blocks are repeated successively within each 5-minute round, and the last 20 s of the round are composed of a sequence (final sprint) of jab, cross and kick in the standing position, completing the 300 seconds, that is, 5 minutes (1 MMA round time). At the end of the 5 min of the first round, the subject recovers for 1 minute and then repeats the process two more times, totalling 3 rounds.

Participants were verbally encouraged at all times to perform as many repetitions as possible while performing

Block	1		2		3	
Technique	Jab/Cross/Kick/Sprawl	Pause	Double leg on the wall	Pause	Ground and Pound	Pause
Duration	20 s	10 s	20 s	10 s	20 s	10 s
Repetitions	3 rounds, with 1 minute rest between them.					
Total duration	5 minutes each round*					
*At the end of each round, perform a 20 s jab-cross-kick (final sprint) in maximal intensity						

Figure 1. Structure of the Anaerobic Specific Assessment for Mixed Martial Arts (ASA$_{MMA}$).

ASA$_{MMA}$, maintaining proper form. In the present study, the individuals wore the heart rate monitor throughout the test to evaluate physiological variables. Thus, the mean heart rate (HR) values (HRMean) were recorded at the end of each round (HRR1, HRR2, HRR3), absolutely (bpm) and relative to the maximum HR (%HRmax) estimated by the Equation 1 (Tanaka et al., 2001):

HRmax= 208 – 0.7 x age   (1)

At the end of each round, blood lactate concentration was also measured.

For the performance data collection during ASA$_{MMA}$ (total sequences of strikes landed per round), a sheet of the scorecard was previously printed and stored in a digital spreadsheet. Due to the importance of knowing the cadence of each round, the fatigue index was also calculated in ASA$_{MMA}$, and the average of the total number of sequences in round 2 and round 3 was added and divided by 2, then this quotient was divided by the total number of sequences in round 1. In this sense, values up to 0.5 were considered as low resistance to fatigue; values up to 0.8 as moderate resistance to fatigue; and values above 0.8 high resistance to fatigue (Paiva & Del Vecchio, 2009). In general, it is indicated that the advanced athletes performed the three rounds of the standard ASA$_{MMA}$ test. However, for safety reasons, the novice participants performed only one round, composed of 5 min of high-intensity intermittent efforts.

Statistical analysis

Descriptive and inferential statistics were used for data analysis. Initially, mean, and respective standard deviations were adopted as measures of centrality and dispersion. Correlation analyses were performed for variables of interest using Pearson's test.

For comparisons between groups (Advanced and Novice), Student's t-test was adopted for independent samples, and the magnitude of the difference was calculated using Cohen's d, which can be classified as small (d= 0.20), medium (d= 0.50) and large (d= 0.8) and very large when d= 1.2 (Sawilowsky, 2009).

In the comparison between rounds for the trained athletes, the analysis of variance (ANOVA) of repeated measures in the moment factor and Bonferroni's post-hoc were applied to locate the differences. In the comparisons between Advanced and Novice, ANOVA was used for repeated measures (moments X groups), using *post-hoc* Tukey for groups and Bonferroni for moments. Prior to the ANOVA, the Mauchly test was performed to test the sphericity of the data and the Greenhouse-Geiser correction was used when necessary (Maia et al., 2004). The magnitude of differences was presented using eta squared (η^2), which can be classified as small (0.1), medium (0.24) or large (0.37) (Cohen, 1988). The significance level was set at 5%.

RESULTS

Data related to the participants' characteristics are presented in Table 1. In it, there were no significant differences for age (p= 0.77; d= 0.13), height (p= 0.21; d= 0, 57), body mass (p= 0.74; d= 0.15), lactate (p= 0.91; d= 0.05), HR at rest and maximum HR estimated by age (p= 0.74; d= 0.15). Only the body fat showed a value close to statistical significance (p= 0.056; d= 0.91). Among the anthropometric variables, there was a significant correlation between body mass and body fat percentage (r= 0.65; p= 0.002; Table 2).

In relation to the heart rate during ASA_{MMA}, it is identified statistically significant differences between groups for HRMean (p< 0.001; d= 2.17), and advanced athletes presented 167± 7, 27 bpm, and novices exhibited 179± 3.8 bpm. The same occurred for values after the first round (p= 0.028; d= 1.07). Regarding the maximum HR percentages, the average HR values in the first round reached 89.2± 11.9% in advanced athletes and 96.3± 3.7% in novices (p< 0.001; d= 2.73). The comparison between rounds was only possible in the group of advanced athletes, given that novice athletes performed only one round (Figure 2, Panel A). Specifically in the advanced group, the analysis of repeated measures of heart rate according to round (rounds 1, 2 and 3) showed no effect for the moment factor ($F_{(2;10)}$= 1.68; p= 0, 21; η^2= 0.16).

Regarding the blood lactate, it is identified that the data after the first round approached the level of significance adopted in the comparison between groups (p= 0.054; d= 0.92) when advanced athletes presented 15.08± 2, 86 mmol/L and novices exhibited 17.15± 1.36 mmol/L. The comparison between rounds was only possible in the group of advanced athletes, given that novice athletes performed only one round (Figure 2, Panel B). Regarding the advanced ones, the analysis of repeated measurements of blood lactate according to round (rounds 1, 2 and 3) showed significant differences between moments ($F_{(2;10)}$= 5.81; p= 0.0111; η^2= 0.39), and the Bonferroni *post-hoc* identified that the difference is located between rounds 1 and 3 (17.3± 2.08 mmol/L; p= 0.045).

There were differences identified between groups considering the number of sequences of movements performed in the first round of ASA_{MMA} (p= 0.003; d= 1.046), with advanced athletes presenting 71.8± 7.87 strikes and novices exhibiting 65.6± 2.87 strikes. The comparison between rounds was only possible in the first group (Figure 3). In relation to the advanced athletes, the analysis of repeated measurements of cadence of strikes according to round (rounds 1, 2

Table 1. Descriptive values (mean± SD) of the sample and comparisons by group.

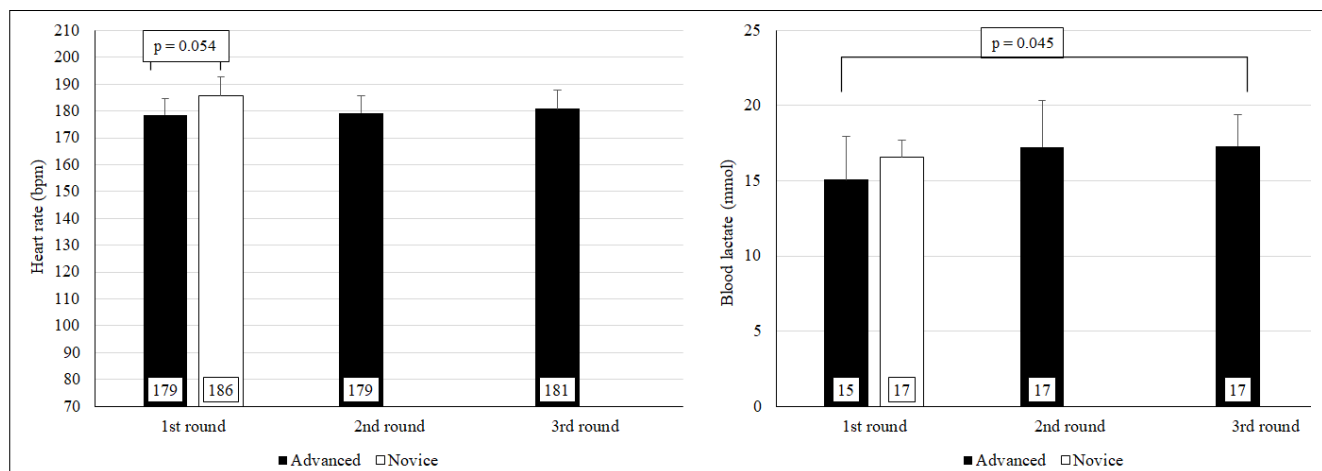|	Advanced (n= 10)		Novice (n= 10)		p-value	Cohen's d
Age (years)	33.80	± 4.80	34.50	± 5.81	0.77	0.13
Height (cm)	179.40	± 9.31	174.90	± 5.99	0.21	0.57
Weight (kg)	88.50	± 20.83	86.00	± 10.68	0.74	0.15
Body fat (%)	17.42	± 7.47	23.97	± 6.85	0.056	0.91
HR maximum (bpm)	186.30	± 4.64	185.50	± 5.81	0.74	0.15
HR rest (bpm)	67.1	± 3.51	68.7	± 3.26	0.30	0.74
Lactate rest (mmol/L)	2.1	± 0.22	2.09	± 0.15	0.91	0.05

HR: heart rate.

and 3) showed statistically significant differences between moments ($F_{(2;10)}= 14.37$; $p< 0.001$; $\eta^2= 0.61$), and the Bonferroni *post–hoc* identified that the differences are located between rounds 1 and 2 ($p= 0.04$), 1 and 3 ($p= 0.005$) and 2 and 3 ($p= 0.017$). Finally, regarding the fatigue index, a performance of 0.90± 0.08 is indicated, and of the 10

**Table 2.** Correlation pairs, with respective Pearson's r and significance level.

Variable 1	versus	Variable 2	n#	Pearson's r		p-value
Body mass (kg)	versus	Body fat (%)	20	0.657	**	0.002
Body fat (%)	versus	HR mean (%HR max)	20	0.474	*	0.035
Body fat (%)	versus	Sequences of movement R1	20	-0.469	*	0.037
Body fat (%)	versus	Sequences of movement R3	10	-0.647	*	0.043
Body fat (%)	versus	Fatigue index	10	-0.682	*	0.030
HR R1 (bpm)	versus	HR R2 (bpm)	10	0.706	*	0.023
HR R1 (bpm)	versus	HR R3 (bpm)	10	0.725	*	0.018
HR R1 (bpm)	versus	HR mean during test (bpm)	20	0.786	***	< 0.001
HR R1 (bpm)	versus	HR mean (%HR max)	20	0.615	**	0.004
HR R2 (bpm)	versus	HR R3 (bpm)	10	0.939	***	< 0.001
HR R2 (bpm)	versus	HR mean during test (bpm)	10	0.792	**	0.006
HR R2 (bpm)	versus	HR mean (%HR max)	10	0.811	**	0.004
HR R3 (bpm)	versus	HR mean during test (bpm)	10	0.702	*	0.024
HR R3 (bpm)	versus	HR mean (%HR max)	10	0.752	*	0.012
HR mean during test (bpm)	versus	HR mean (%HR max)	20	0.840	***	< 0.001
HR mean during test (bpm)	versus	Lactate in round 1	20	0.457	*	0.043
HR mean during test (bpm)	versus	Sequences of movements R1	20	-0.538	*	0.014
HR mean (%HR max)	versus	Sequences of movements R1	20	-0.601	**	0.005
Lactate R2	versus	Lactato R3	10	0.852	**	0.002
Sequences of movements R1	versus	Sequences of movements R2	10	0.863	**	0.001
Sequences of movements R1	versus	Sequences of movements R3	10	0.855	**	0.002
Sequences of movements R2	versus	Sequences of movements R3	10	0.985	***	< 0.001
Sequences of movements R2	versus	Fatigue index	10	0.766	**	0.010
Sequences of movements R3	versus	Fatigue index	10	0.778	**	0.008

#n varied according to the number of athletes observed (only advanced or advanced plus novice); *$p< 0,05$, **$p< 0,01$, ***$p< 0,001$; R1, R2, and R3: rounds 1, 2, and 3; HR: heart rate.

Figure 2. (A) Heart rate and (B) lactate, according to group and round.

*Different from novices (*p*= 0.003), @ Different from Round 1, # Different from Round 2.
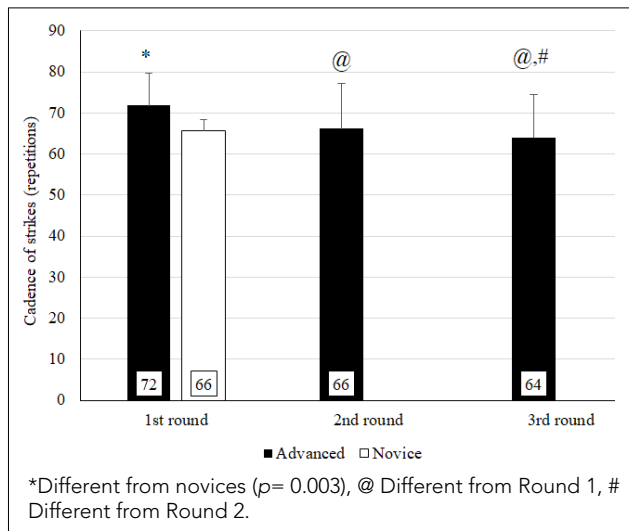
Figure 3. Sequences of movements by group (advanced and novice) and round.

advanced athletes, only one presented a score classified as moderate (0.74).

The correlational analyses present significant values between anthropometric, physiological, and physical performance parameters in Table 2.

DISCUSSION

The purpose of the present study was to investigate the physiological and physical performance responses of advanced and novice practitioners in a specific MMA test. The main findings of the present study indicated that (i) the participants did not differ in terms of age, body composition, HR and resting lactate, (ii) HR at the end of the first round was higher in the novice athletes, (iii) in the advanced group, the lactate values at the end of the third round were higher than the values of the first round and, finally, (iv) among advanced group, the number of sequences of strikes was higher than for novices, decreasing over the rounds.

The evaluation of MMA athletes was widely performed with nonspecific tests of strength, power, flexibility, and cardiorespiratory fitness (Andrade et al., 2019; Bueno et al., 2022; Plush et al., 2021). However, there is a lack of specific tests, as the Anaerobic Specific Assessment for Mixed Martial Arts (ASA$_{MMA}$), a procedure that was developed considering: i) duration of MMA fights (Bounty et al., 2011), ii) the temporality of the combats in relation to the periods of effort and pause (Miarka et al., 2016; Coswig et al., 2016), and iii) the technical-tactical dynamics, considering the most used techniques (Del Vecchio et al., 2011).

In a recent investigation, Andrade et al. (2022) tested the reproducibility of ASA$_{MMA}$ with 12 amateur fighters and found no significant differences between test and retest, with intraclass correlation coefficients between 0.5 (movement sequences) and 0.9 (rating of perceived exertion). Complementarily, values lower than 5% were observed in the coefficient of variation (CV) for most of the variables measured (between 3.1% and 4.3%), although values close to 10% were identified in the fatigue index. Finally, significant correlations were identified between ASA$_{MMA}$ performance and maximal oxygen consumption in the incremental test (*r*= 0.67; *p*< 0.05) and aerobic capacity (*r*= 0.96; *p*< 0.05), but the absence of correlations with the Wingate test (30 s), probably due to the duration of the tests (Andrade et al., 2022).

Heart rate is a relevant parameter to evaluate and monitor in combat sports athletes (Slimani et al., 2018). Various tests, such as the Special Judo Fitness Test (Franchini et al., 2009), correlate heart rate with the number of projections, with a lower index in the test revealing better performance. From a physiological point of view, the average HR (absolute and relative) during the first test round was higher in the group of novice athletes, which may be due to better aerobic fitness among advanced fighters (Del Vecchio & Ferreira, 2013), promoting lower cardiorespiratory demand during ASA$_{MMA}$ (Bounty et al., 2011).

Regarding blood lactate, it is indicated that it is associated with the glycolytic demand of physical exertion. In this sense, official or simulated MMA fights present values close to 16 mmol/L (Coswig et al., 2016), values similar to those found in the present study — and which indicate a high demand for the anaerobic component of energy supply (Del Vecchio et al., 2011). Considering that high values of blood lactate can affect muscle contractility mechanisms by interfering with interactions at the level of cross bridges, this could partially explain the loss of performance over the rounds, inferred by the reduction in the number of sequences of movements. However, the present study highlights a high resistance to fatigue in Trained fighters, given that only one presented a moderate index. In this sense, with regard to more successful fighters, it is indicated that memos are more tolerant to lactate (lactic tolerance), as well as a greater buffering capacity of the hydrogen cation in the blood, providing greater muscular resistance (Aschenbach et al., 2000).

Regarding the evaluative and competitive context, sports modalities have been studied regarding several physiological parameters, such as quantification of heart rate and blood lactate concentration. However, the analysis of specific movements is also relevant in order to clarify the physical performance of the competitor, and in the present study, the values

were statistically different between Advanced and Novice athletes, evidencing the relevance of this variable in the evaluation routines (Andrade et al., 2019; Andrade et al., 2022).

The present study demonstrates the usefulness of ASA_{MMA} as an evaluation and even training adjustment, given that all subjects showed a significant decrease in the sequence of specific high-intensity movements and concise indicative of fatigue and muscle wasting during the test, in addition to stimulation of the anaerobic energy systems lactic or glycolytic that are considered decisive for the best competitive performance (Del Vecchio et al., 2011). Due to the degree of specificity and physiological demand observed in the present study, the ASA_{MMA} can be used as part of the periodization monitoring of combat modality athletes, as it presents simulations of situations of competitive conditions close to reality (Del Vecchio et al., 2011; Miarka et al., 2016; Coswig et al., 2016).

It is also verified that other modifications can be made according to the opponent and the predominant style of the fighter since the technical and tactical aspects are directly related to the performance and the result of the fight, and recent studies point to technical variation as a fundamental element for unpredictability in high-performance competitions (Miarka et al., 2016).

CONCLUSION

Based on the results obtained, we can conclude that ASA_{MMA} can discriminate between advanced and novice athletes, both from a physiological point of view (using heart rate as an indicator) and from a physical point of view, based on the number of sequences of movements. It is indicated that the model presented in the study presents movement specificity and the relation between effort/pause. Thus, it can be used as an integral part of planning specific training for MMA and serving as a performance evaluation tool to measure the evolution in the development of physical or technical-tactical fitness of MMA athletes.

REFERENCES

Andrade, A., Flores, M. A., Andreato, L. v., & Coimbra, D. R. (2019). Physical and training characteristics of mixed martial arts athletes: systematic review. *Strength & Conditioning Journal*, *41*(1), 51-63. https://doi.org/10.1519/SSC.0000000000000410

Andrade, V. L., Foresti, Y. F., Almeida, P. B., Araujo, M. Y. C., Kalva-Filho, C. A., & Papoti, M. (2022). Validity and reliability of a specific anaerobic test for mixed martial arts. *Science & Sports*, *37*(5-6), 488.e1-488.e10. https://doi.org/10.1016/j.scispo.2021.10.006

Aschenbach, W., Ocel, J., Craft, L., Ward, C., Spangenburg, E., & Williams, J. (2000). Effect of oral sodium loading on high-intensity arm ergometry in college wrestlers. *Medicine & Science in Sports & Exercise*, *32*(3), 669-675. https://doi.org/10.1097/00005768-200003000-00018

Atkinson, G., & Nevill, A. M. (2001). Selected issues in the design and analysis of sport performance research. *Journal of Sports Sciences*, *19*(10), 811-827. https://doi.org/10.1080/026404101317015447

Bounty, P. la, Campbell, B. I., Galvan, E., Cooke, M., & Antonio, J. (2011). Strength and Conditioning Considerations for Mixed Martial Arts. *Strength & Conditioning Journal*, *33*(1), 56-67. https://doi.org/10.1519/SSC.0b013e3182044304

Bueno, J. C. A., Faro, H., Lenetsky, S., Gonçalves, A. F., Dias, S. B. C. D., Ribeiro, A. L. B., da Silva, B. V. C., Filho, C. A. C., de Vasconcelos, B. M., Serrão, J. C., Andrade, A., Souza-Junior, T. P., & Claudino, J. G. (2022). Exploratory systematic review of mixed martial arts: an overview of performance of importance factors with over 20,000 athletes. *Sports*, *10*(6), 80. https://doi.org/10.3390/sports10060080

Chaabène, H., Hachana, Y., Franchini, E., Mkaouer, B., Montassar, M., & Chamari, K. (2012). Reliability and construct validity of the karate-specific aerobic test. *Journal of Strength and Conditioning Research*, *26*(12), 3454-3460. https://doi.org/10.1519/JSC.0b013e31824eddda

Chernozub, A., Manolachi, V., Korobeynikov, G., Potop, V., Sherstiuk, L., Manolachi, V., & Mihaila, I. (2022). Criteria for assessing the adaptive changes in mixed martial arts (MMA) athletes of strike fighting style in different training load regimes. *PeerJ*, *10*, e13827. https://doi.org/10.7717/peerj.13827

Cohen, J. (1988). *Statistical power analysis for the Behavioral Sciences* (2nd ed.). Lawrence Erlbaum Associates.

Collier, T., Johnson, A. L., & Ruggiero, J. (2011). Aggression in mixed martial arts: an analysis of the likelihood of winning a decision. In: Jewell, R. (Ed.), *Violence and Aggression in Sporting Contests* (pp. 97-109). Springer. https://doi.org/10.1007/978-1-4419-6630-8_7

Coswig, V. S., Hideyoshi Fukuda, D., de Paula Ramos, S., & Del Vecchio, F. B. (2016). Biochemical differences between official and simulated mixed martial arts (MMA) matches. *Asian Journal of Sports Medicine*, *7*(2), e30950. https://doi.org/10.5812/asjsm.30950

da Silva Junior, J. N., Kons, R. L., de Lucas, R. D., & Detanico, D. (2022). Jiu-Jitsu-specific performance test: reliability analysis and construct validity in competitive athletes. *Journal of Strength and Conditioning Research*, *36*(1), 174-179. https://doi.org/10.1519/JSC.0000000000003429

Del Vecchio, F. B., & Ferreira, J. L. M. (2013). Mixed martial arts: rotinas de condicionamento e avaliação da aptidão física de lutadores de Pelotas/RS. *Revista Brasileira de Ciências do Esporte*, *35*(3), 611-626. https://doi.org/10.1590/S0101-32892013000300007

Del Vecchio, F. B., Hirata, S. M., & Franchini, E. (2011). A review of time-motion analysis and combat development in mixed martial arts matches at regional level tournaments. *Perceptual and Motor Skills*, *112*(2), 639-648. https://doi.org/10.2466/05.25.PMS.112.2.639-648

Franchini, E., Del Vecchio, F. B., & Sterkowicz, S. (2009). A special judo fitness test classificatory table. *Archives of Budo*, *5*, 127-129.

Jackson, A. S., & Pollock, M. L. (1978). Generalized equations for predicting body density of men. *British Journal of Nutrition*, *40*(3), 497–504. https://doi.org/10.1079/BJN19780152

Kirk, C., Langan-Evans, C., Clark, D. R., & Morton, J. P. (2021). Quantification of training load distribution in mixed martial arts athletes: A lack of periodisation and load management. *PLoS One*, *16*(5), e0251266. https://doi.org/10.1371/journal.pone.0251266

Maia, J. A. R., Silva, R. G., Seabra, A., Lopes, V. P., Prista, A., & Freitas, D. L. (2004). Uma nota didáctica breve no uso esclarecido de procedimentos estatísticos em análise de dados repetidos no tempo. Um estudo guiado para investigadores em Ciências do Desporto. *Revista Portuguesa de Ciências do Desporto*, *4*(3), 115-133.

Malanowski, S., & Baima, N. R. (2021). On the martial arts status of mixed martial arts. In: Malanowski, S., & Baima, N. R. (Eds), *The Philosophy of Mixed Martial Arts* (pp. 16-29). Routledge. https://doi.org/10.4324/9781003122395-3

Manning, J., & Pickup, L. (1998). Symmetry and performance in middle distance runners. *International Journal of Sports Medicine, 19*(3), 205-209. https://doi.org/10.1055/s-2007-971905

Manning, J. T., & Taylor, R. P. (2001). Second to fourth digit ratio and male ability in sport: implications for sexual selection in humans. *Evolution and Human Behavior, 22*(1), 61-69. https://doi.org/10.1016/S1090-5138(00)00063-5

Marković, M., Kukić, F., Dopsaj, M., Kasum, G., Toskic, L., & Zaric, I. (2021). Validity of a novel specific wrestling fitness test. *Journal of Strength and Conditioning Research, 35*(12S), S51-S57. https://doi.org/10.1519/JSC.0000000000003538

Martin, T. G., Williams, A. S., Whisenant, W., & Dees, W. (2015). Mixed martial arts (MMA) and the media: an examination of an emerging sport's coverage in ESPN the magazine. *Public Organization Review, 15*(3), 433-452. https://doi.org/10.1007/s11115-014-0283-x

Miarka, B., Coswig, V., Brito, J. C., Slimani, M., Amtmann, J., & Del Vecchio, F. B. (2016). Comparison of combat outcomes: technical and tactical analysis of female MMA. *International Journal of Performance Analysis in Sport, 16*(2), 539-552. https://doi.org/10.1080/24748668.2016.11868907

Paiva, L., & del Vecchio, F. B. (2009). *Pronto pra guerra: preparação física específica para luta & superação*. OMP.

Plush, M. G., Guppy, S. N., Nosaka, K., & Barley, O. R. (2021). Developing a Comprehensive Testing Battery for Mixed Martial Arts. *International Journal of Exercise Science, 14*(4), 941-961.

Ross, A. J., Ross, B. J., Zeoli, T. C., Brown, S. M., & Mulcahey, M. K. (2021). Injury profile of mixed martial arts competitions in the United States. *Orthopaedic Journal of Sports Medicine, 9*(3). https://doi.org/10.1177/2325967121991560

Sawilowsky, S. S. (2009). New effect size rules of thumb. *Journal of Modern Applied Statistical Methods, 8*(2), 597-599. https://doi.org/10.22237/jmasm/1257035100

Schaffarczyk, M., Rogers, B., Reer, R., & Gronwald, T. (2022). Validity of the polar h10 sensor for heart rate variability analysis during resting state and incremental exercise in recreational men and women. *Sensors, 22*(17), 6536. https://doi.org/10.3390/s22176536

Siri, W. E. (1961). Body composition from fluid spaces and density: analysis of methods. 1961. *Nutrition, 9*(5), 480-491.

Slimani, M., Znazen, H., Sellami, M., & Davis, P. (2018). Heart rate monitoring during combat sports matches: a brief review. *International Journal of Performance Analysis in Sport, 18*(2), 273-292. https://doi.org/10.1080/24748668.2018.1469080

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology, 37*(1), 153-156. https://doi.org/10.1016/S0735-1097(00)01054-8

Tayech, A., Mejri, M. A., Chaabene, H., Chaouachi, M., Behm, D. G., & Chaouachi, A. (2019). Test-retest reliability and criterion validity of a new Taekwondo Anaerobic Intermittent Kick Test. *Journal of Sports Medicine and Physical Fitness, 59*(2), 230-237. https://doi.org/10.23736/S0022-4707.18.08105-7