Original Article

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Anthropometric and Physiological Characteristics of Young Elite Hungarian Motocross Riders in Motocross Competitions

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Abstract: *Background*: Motocross riders' performance is highly dependent on the characteristics of the motorcycles and the skills of the riders, and the actual environmental conditions. This study aims to describe the differences in anthropometric and physiological characteristics between internationally ranked adolescent males and nationally ranked motorcross (MX) peer competitors; *Methods*: Data obtained from young riders (n=14) were divided into internationally ranked G_1 (n=5) and - nationally ranked G_2 (n=9) young MX riders. We determined body composition and cardiorespiratory variables, and measured heart rate and movement-related data with Polar Team Pro system during the race; (3) *Results*: Blood lactate concentrations were evaluated before and after the race session. MX riders with an international ranking performed significantly better during both races (R_1 and R_2), which manifested itself in significantly shorter times per lap on average (difference for R_1=14.8 s and for R_2=16.7 s, respectively, p=0.017), more laps completed (G_1 vs G_2 approx.: 11.2 : 9.9 laps for R_1 and R_2, p=0.019) and points scored (difference: R_1=9.3 pts and R_2=9.0 pts, p=0.014). There were no statistically significant differences in age between the two compared groups (p=0.559) and other anthropometric and physiological characteristics tested, with an exception of muscle mass percent (p<0.001); *Conclusions*: Current results showed that motocross probably places a heavy burden on riders, who need to be fit enough to maintain their position in the field.

Keywords: cardiorespiratory indicators; somatic features; motorcross performance; blood lactate; body composition

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INTRODUCTION

Motocross (MX) is an off-road race where the rider's performance is determined by the combined effects of the rider's motorcross skills, motorcycle and the environment [1]. It takes place on natural, pre-designated terrain, where the uneven ground (holes, gullies, and ups and downs) present a challenge to riders. According to Gobi et al. [2], MX is a competition of high-speed, on a fairly rough 2 km course on natural terrain that allows riders to perform jumps 20 m in length and 5 meters in height jumps, on dirt, mud, sharp turns and steep slopes. Each race has a maximum of 40 riders, who all line up at the start to racing around the course as fast as possible for a set time of 30-40 minutes. The motorcycles are divided into different categories based on their engine size. The race consists of two "clashes" with a short break between them.

The motorcycle, weighing between 85 and 110 kg and travelling at high speed, must be controlled by the rider over the difficult terrain, keeping an eye on the competitors and their own position. Each rider must react quickly to the motorcycle's sudden and violent movements and constantly changing terrain. This requires motorcycling skill, muscle power and endurance, and induces a stress on the cardiovascular system. These unique characteristics are strongly related and depend on various sized motorcycles (e.g., 125-cc 2-stroke, 250-cc 2-strokeand 4-stroke, and 450-cc 4-stroke), require frequent changes of direction, forces, velocity, and acceleration [3]. For this reason, technical skills are considered more important than physiological characteristics in motor sports [4]. The duration of the race and the frequent changes of direction and speed due to the characteristics of the course involve the continuous involvement of all muscle groups of the body [5]. Therefore, (MX) requires the use of whole-body musculature in aerobic and anaerobic energy systems, as well as the skills needed to control a motorcycle on a challenging course [6]. For this reason, especially in the enduro category, both aerobic and lactic acid metabolism play a role [7, 8]. During a race, the average heart rate has been reported to be 90-100% of the maximum heart rate [9]. At the start, the heart rate was (~120 beats/min), increasing to (180 beats/min) after the first 30 seconds. For the remaining time of the race, the heart rate ranged between (190 and 195 beats/min). Von Lehmann et al. [10], measured a heart rate of (180-190 beats/min), a blood lactate concentration of 6-8 mmol/L, and a VO_2 of 2.1 L/min in the sixth minute of the race in 250cc riders [3]. Lactate levels within 2 minutes after the enduro race are 1.5±0.3 mM, and increase to 3.8±1.3 mM after high speed trials. Lactate accumulation leads to muscle fatigue and decreases the muscle force available for control of the motorcycle [3-10]. In addition to muscular activity, psycho-emotional factors also increase physiological workload, which is manifested, among other things, by an increase in heart rate. Motocross training and racing requires high alertness and readiness (arousal), [9]. Even though motocross is both physiologically and mentally challenging, research on the sport has focused on injury and risk factors.

To the best of our knowledge, there are only few studies that contain all three areas of research: anthropometric, physiological, pacing, and athletes aspiring to become one of the best MX riders. The method of combining human anthropometric and physiological characteristics with race pace factors can allow for a better understanding of the MX performance for the selection process. Based on the stated purpose of the study, an attempt was made to answer the questions: (1) what are the anthropometric and physiological profiles of young motocross riders, as well as, (2) do these profiles differ significantly between motocross riders with international and national rankings ?

MATERIAL AND METHODS

Participants

Fourteen Hungarian elite motocross riders volunteered for this cross-sectional study, with all of them regularly trained and competed in national and international age-

group competitions. From these riders, two groups were created, G_1 (N=5) - internationally ranked and G_2 (N=9) - nationally ranked young motocross riders. The G_1 group is made up of riders who have been riding motorcycles with the help of their families since they were small children (6-7 years old). They train together every year in a training camp and are age group champions in national and international competitions.
Furthermore some of the surveyed young motocross drivers with international rankings have already achieved serious success at junior world championship competitions. The mean of their anthropometric characteristics was as follows: age (G_1=14.0 ± 2.3 years), body height (166.2 ± 6.3 cm), body mass (58.1 ± 5.1 kg), BMI (20.5 ± 1.7 kg/m^2); age (G_2 = 13.2 ± 2.2 years), body height (150.3 ± 18.3 cm), body mass (51.4 ± 8.4 kg), BMI (20.1 ± 4.3 kg/m^2). Each participants and their parents were provided with detailed information about the purpose of the study, potential risks, measurement methods, and the techniques in motor tests that could be practiced during practice sessions held directly before the study. After participants and their parents were fully informed about the procedures and the potential risks of the experiment, written informed consent was obtained from the parents.

Study design

Prior to the motor tests, all participants were familiarized to the purpose of the study and to the technique of performing individual motor tests. The technique of performing the tests was practiced in the week preceding the main study during two sessions separated by a two-day break. The motocross riders' coaches were instructed not to engagege the subjects in any strenuous training the day before the trial, and they assisted the authors in performing measurements. The tests were carried out in the laboratory of exercise physiology at Eötvös Lóránd University, Budapest in 2022. All laboratory sessions were carried out in the last month before the start of the Hungarian age group (for 15 years old) championship at the end of the competitors' preparation period. The participants visited the laboratory once, where anthropometric characteristics were measured first. According to the planned protocol, anaerobic capacity was assessed on the treadmill ergometer, together with analysis of exhaled gases and heart rate laboratory tests were performed by the same investigators and at the same time of day, in the morning (8:00-12:00). Subjects were asked to refrain from vigorous exercise and to arrive rested during the 24 hours before to the laboratory test. The participants were instructed to eat a light meal (800–1,200 kcals) containing mainly carbohydrates (60–70%) not later than 3–4 h before the study [11].

Anthropometry and Body Composition

The anthropometric characteristics were measured by a trained ISAK-accredited expert (Level 1) by the standardized procedures of the International Society for the Advancement of Kinanthropometry. Body height (BH) was measured to the nearest 0.1 cm using a patient weighing scale with a height rod (Seca 217, Hamburg, Germany) without shoes. Body mass (BM), after the removal of shoes and heavy clothing, was measured to the nearest 0.1 kg. Body composition characteristics (fat mass percent FMP% [%] and muscle mass percent – MMP% [%]) were measured for 120 min after the fluid consumption in the standing position via the InBody 720 Tetrapolar 8-Point Tactile Electrode System (Biospace Co., Ltd., Seoul, Korea) commonly used in such types of research [12]. Body composition measurements were performed in accordance with measurement guidelines.

Maximal Cardiorespiratory Testing

The cardiorespiratory test was conducted at Eötvös Lóránd University of the Laboratory of Exercise Physiology using the Piston instrument (EN ISO 13485:2016, Budapest, Hungary). Ergospirometric tests were performed before the beginning of the competition season, following a progressive intensity protocol until voluntary exhaustion (failure) on a motorized treadmill (Pulsar 4.0, h/p/Cosmos Sports & Medical GmbH, Nußdorf, Germany). All participants participated in the test after two light adaptation training sessions to minimize injuries. Resting heart rate (HR_{rest}) was measured in a laboratory setting by averaging the data for the last 5 min of 20-minute sitting resting records. Before starting the workload, the competitors performed standardized warm-up consisting of 5 min of low- to moderate-intensity cardiorespiratory exercise on BikeERG Concept2 (Concept2 Inc., Vermont, USA), followed by 5 min of static stretching. The test protocol began with an initial speed of 5 km/h (walk) for one minute and continued at 8 km/h. Thereafter, the treadmill speed was increased by 1 km/h every two minutes, inclination was set on 2°. The competitors were instructed to run to exhaustion and were given strong verbal encouragement to perform at their best during the test. Respiratory gas exchange was monitored continuously with a portable breath-to-breath gas analyzer (PRE-201/cc and PRE-201/pm). The analyzer was calibrated according to the manufacturer's instructions before each trial run. The following cardiorespiratory variables were monitored: heart rate - HR [beat/min], oxygen uptake - VO_2 [L/min], carbon dioxide production - VCO_2 [L/min], respiratory exchange ratio – RER [arbitrary units; AU) expressed as the ratio of two metabolites (VCO_2/VO_2), minute ventilation -VE [L/min], and relative oxygen uptake rVO_2 at the anaerobic threshold (AT) - rVO_2/AT [mL/kg/min]. The anaerobic threshold pulse (ATP) was determined after the completion of the exercise test; ATP was determined for each subject using the V-slope method developed by Beaver et al. [13]. This method involves an analysis of the VCO_2/VO_2 response on the assumption that the threshold value corresponds to the breakpoint of the VCO_2/VO_2 relationship and the corresponding VO_2, VCO_2, and RER values were averaged over 10-s periods, and the highest 30-s value (i.e., three consecutive 10-s periods) was used in the analysis. This method involves an analysis of the VCO_2/VO_2 response on the assumption that the threshold value corresponds to the breakpoint of the VCO_2/VO_2 relationship and the corresponding HVE, VO_2, VCO_2, and RER values ER were averaged over 10-s periods, and the highest 30-s value (i.e., three consecutive 10-s periods) was used in the analysis. Heart rate was continuously monitored (at 5-s intervals) before and during the test using a chest transmitter and receiver (Garmin HRM3-SS, Garmin Ltd., Olathe, KS, USA). The VO_{2max} value was accepted if at least three criteria were met: (1) HR in the last minute exceeded 90% of the subject's age-predicted HR_{max}, which was calculated previously with the use of the equation proposed by [14]; (2) the VO_2 plateau reached 150 mL/min with an increase in power output; (3) RER reached or exceeded 1.1 AU, and the subjects were unable to continue running despite verbal encouragement. We determined the respiratory threshold point (VTP), [13], maximal heart rate (MP) means - the highest heart rate during exercise and the respiration compensation point (RCP) [15].

Measurements during competition

The MX drivers participated in three competitions, two of which were national and one international. All three races were held on the indicated track (Figure 1) in the spring and summer of 2022. The weather conditions were almost identical, and the riders' state of preparation was also adequate to that race course. The averages of locomotor and mechanical characteristics measured in the three competitions were calculated and compared between the two groups (Table 2). Heart rate (HR) and movement-related data were recorded with the Polar Team Pro® system (Polar Electro, Kempele, Finland). The system consists of a chest belt with a sensor unit (Polar H7 Bluetooth 4.0 smart chest band) with built-in ECG electrodes, a 10 Hz integrated GPS, and a 200 Hz microelectromechanical systems motion sensor. Data were transmitted to the Polar Beat software (v3.5.4). From the recorded physiological and physical data, race session. The (HR) measurement system was switched on immediately before and off immediately after each race.

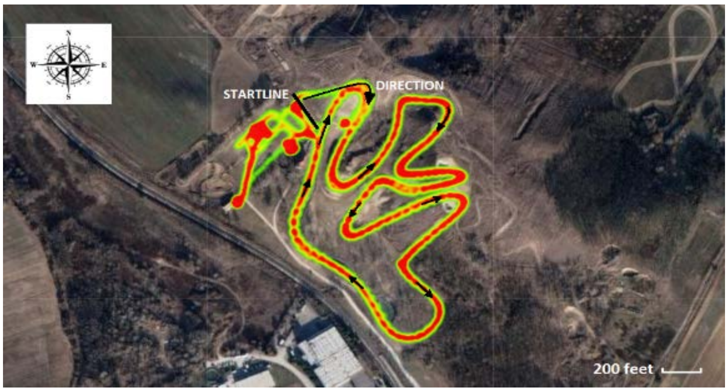

Figure 1. Description of the race track structure: Satellite image of the motocross competition. Piliscsév, Motorsport Centrum (Hungary). Classification: national and international FIM-registered track. Track length: 1990 m., track width: 6-8 m., level difference: 30 m., number of jumps: 14, number of bends: 13, track surface: earthy clay, sandy in places. Temperature: 18-20 C, soil quality: ideal, watered. Number of competitors: ~160, in different categories.

Measurements before and after competition

To determine the metabolic response of the competition session, we evaluated the blood lactate concentrations 5 minutes before and 5 minutes after the race session. Blood samples (25 μL) were collected from the fingertips into heparinized capillary tubes and transferred to microtubes containing (50 μL) of 1% sodium fluoride. The lactate concentration was analyzed via an electro-enzymatic method with a lactate analyzer (YSI 2300 Stat Analyzer, Yellow Springs Instruments, Yellow Springs, OH, USA) before and after the first (R_1) and second (R_2) races. Blood lactate concentrations are expressed in millimoles (mmol/L).

Statistical analysis

The anthropometric, body composition and physiological characteristics of the riders from two groups, as well as, the cardiovascular characteristics recorded during the races and the differences between the two groups by race were analyzed using independent samples t-tests. Hedges' g effect size t measurement/indicator was calculated, the difference in means between the two groups was taken and the result was divided by the pooled standard deviation. The relationship between variables recorded in the laboratory (RP, MP, VO_{2max}, VCO_{2max}, P) and during the competition (locomotor and mechanical). we used "simple" Bonferroni correction, alpha/number of variables, if $p < 0.004$, the association is statistically significant. As the reported Pearson's correlation coefficient is an effect size indicator, we interpreted significant large associations ($p < 0.004$ and $r > 0.4$). The level of significance, alpha, was set a priori at 0.05 (results were considered statistically significant at $p < 0.05$). Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp. Released 2017. Armonk, NY: IBM Corp).

Ethics committee

This research was conducted in accordance with the guidelines and policies of the Research Ethics Committee (IV/3043–2/2022/EKA), Hungary, and the Declaration of Helsinki.

RESULTS

Table 1 presents a comparative analysis of MX riders with international (G_1) and national rankings (G_2). There were no statistically significant differences in age between the two compared groups ($t = 0.61$, $p = 0.559$). We have found significant differences in training age (Ta) and relative muscle mass (MMP); MMP ($t= 1.761$, $p<0.001$); Ta ($t=7.019$, $p<0.001$).

Table 1. Anthropometric, body composition and physiological characteristics of the young motocross cyclist

Characteristics	Total (n=14)		G_1 (n=5)		G_2 (n=9)		QD G_1 vs G_2	t	p	g
	M	SD	M	SD	M	SD				
Age [year]	13.62	3.15	14.0	2.31	13.2	2.21	0.81	0.611	0.559	0.17
Ta [year]	5.214	3.09	8.00	2.16	3.22	0.83	4.78	7.019	<0.001	0.57
BH [cm]	159.97	14.83	166.6	6.33	153.28	18.34	13.4	1.689	0.122	0.33
BM [kg]	52.42	14.32	58.15	5.10	51.41	8.67	6.72	1.452	0.177	0.25
BSA [m^2]]	1.62	0.20	1.70	0.16	1.53	0.26	0.17	1.560	0.149	1.83
FMP [%]	11.88	5.44	10.18	1.98	13.58	6.82	-3.42	0.776	0.437	0.05
MMP [%]	40.20	10.24	41.65	1.79	38.74	3.68	2.91	1.761	<0.001	0.49
BMI [kg/m^2]	20.34	3.76	20.55	1.68	20.13	4.30	0.42	0.183	0.858	0.53
RA $_{LBM}$ [kg]	1.72	1.28	1.26	0.49	1.29	0.29	-0.03	0.108	0.918	0.07
LA $_{LBM}$ [kg]	1.70	1.28	1.29	0.49	1.27	0.30	0.02	0.084	0.936	0.05
RL $_{LBM}$ [kg]	5.62	4.24	3.97	1.34	4.39	0.91	-0.42	0.628	0.553	0.37
VT [bpm]	177.63	3.71	175.63	1.94	178.62	4.90	-3.0	-1.559	0.145	0.14
MP [bpm]	198.81	3.72	197.84	1.79	199.48	4.45	-1.6	-0.780	0.449	0.29
RCP [bpm]	186.35	2.23	185.47	1.14	186.83	2.58	-1.4	1.116	0.286	0.39
LL $_{LBM}$ [kg]	5.59	4.17	3.92	1.35	4.32	0.91	-0.40	0.591	0.576	0.35
VO_{2max} [L/min]	2624.85	720.36	2657.60	924.83	2606.66	643.75	-32.82	0.121	0.905	0.23
VCO_{2max} [L/min]	2819.85	1149.54	2978.60	1351.94	2731.66	1099.55	247.31	0.716	0.416	0.21
O_2P [bpm]	16.30	2.02	15.54	1.73	16.87	2.03	-2.37	0.674	0.258	0.17
PO [W]	306.00	207.64	218.20	91.12	201.78	64.51	16.42	0.356	0.733	0.21

G_1 – international ranking MX riders, G_2 – national ranking MX riders, QD – quantitative differences between means, BH - body height [cm], BM - body mass [kg]. Ta-training age [year] BSA - body surface area [m^2], FMP - fat mass percent [%], MMP - muscle mass percent [%], BMI - body mass index [kg/m^2], RA LBM - right arm lean body mass [kg], LALBM - left arm lean body mass [kg], RL LBM - right leg lean body mass [kg], LLLBM - left leg lean body mass [kg], VT –ventilation threshold [bpm], MP - the highest heart rate during exercise [bpm], RCP - respiration compensation point [bpm], PO – power output [W].

Table 2 presents comparison between G_1 and G_2 in the first (R_1) and second (R_2) races. Considering the average time per lap, in both R_1 and R_2 its values were significantly shorter among MX riders with international ranking (G_1: 109.9 and 109.4 s, respectively) compared to MX riders presenting national ranking (G_2: 124.7 and 126.1, respectively. Furthermore, in both groups together (G_1 and G_2), the average times per lap were shorter (R_1 vs R_2 = 119.8: 120.2 s). During the first race (MX) readers from G_1 were in the effort intensity range of HR (90-100%) ($p = 0.034$, $t=1.65$) for a significantly longer period of time and reached higher top speed max ($p = 0.027$, $t = 2.93$) than the representatives of G_2. Surprisingly, during the second race, (MX) riders from G_2 stayed significantly longer in terms of effort intensity range HR (90-100%) ($p = 0.041$, $t = -1.53$) and performed significantly lower distance of sprints ($p = 0.0022$, $t = 2.68$), but no significant differences in the speed max were found.

Considering the average time per lap, in both R_1 and R_2 its values were significantly shorter among MX riders with international ranking (G_1: 109.9 and 109.4 s, respectively) compared to MX riders presenting national ranking (G_2: 124.7 and 126.1, respectively. Furthermore, in both groups together (G_1 and G_2), the average times per lap were shorter (R_1 vs R_2 = 119.8: 120.2 s). The representatives of G_1 also performed significantly ($p<0.05$) more laps and scored significantly more points in both races.

Table 2. Comparison (G_1 vs G_2) of the physiological and kinematic characteristics of the young (MX) readers (by Polar Team Pro) based on the first (R_1) and second (R_2) race

Race	Characteristics	Total (n=14)		G_1 n=5		G_2 n=9		QD G_1 vs G_2	t	p	g
		M	SD	M	SD	M	SD				
First (R_1)	Average lap time (s)	119.83	11.55	109.94	10.78	124.73	9.00	-14.79	-2.752	**0.017**	1.46
	HR_{rest} (bpm)	72.07	9.94	67.40	8.71	74.67	10.07	-7.27	-1.413	0.189	0.71
	HR_{max} (bpm)	195.79	7.66	196.40	7.16	195.44	8.32	0.96	0.225	0.826	0.11
	HR (70-80%)* (s)	179.86	72.11	161.40	44.85	190.11	84.34	-28.71	-0.831	0.422	0.37
	HR (80-90%)* (s)	422.57	377.95	327.80	399.22	475.22	379.08	-147.42	-0.674	0.519	0.36
	HR (90-100%)* (s)	713.64	458.00	885.40	363.66	618.22	496.04	267.18	1.652	**0.034**	0.55
	$Speed_{max}$ (km/h)	73.91	7.94	79.93	10.17	71.23	6.47	8.70	2.935	**0.027**	0.56
	$Speed_{avg}$ (km/h)	35.67	7.06	37.21	2.80	34.81	8.64	2.41	0.766	0.460	0.31
	Cadence (rpm)	94.61	2.85	94.90	3.88	94.44	2.36	0.46	0.239	0.819	0.14
	Sprints (m)	199.86	19.45	213.00	15.17	198.56	18.21	20.44	1.246	0.249	0.19
Second (R_2)	Average lap time (s)	120.15	11.72	109.43	9.03	126.10	8.42	-16.67	-3.462	**0.004**	1.76
	HR_{rest} (bpm)	71.09	7.68	69.30	6.78	72.58	9.16	-11.28	-0.517	0.439	0.17
	HR_{max} (bpm)	194.50	6.99	191.40	10.06	196.22	4.41	-4.82	-1.018	0.356	0.66
	HR (70-80%)* (s)	214.71	129.48	270.20	177.39	183.89	92.30	86.31	1.014	0.355	0.64
	HR (80-90%)* (s)	306.21	235.98	449.40	271.80	226.67	183.37	222.73	1.637	0.152	0.96
	HR (90-100%)* (s)	843.57	353.24	648.20	482.29	952.11	222.17	-303.91	-1.533	**0.041**	0.86
	$Speed_{max}$ (km/h)	67.48	7.48	68.58	9.06	66.87	6.97	1.71	0.365	0.726	0.21
	$Speed_{avg}$ (km/h)	30.47	9.04	28.32	6.76	31.67	10.27	-3.35	-0.734	0.478	0.34
	Cadence (rpm)	95.07	2.23	96.10	2.27	94.50	2.12	1.60	1.291	0.233	0.69
	Sprints (m)	201.79	22.18	218.40	15.32	192.56	20.34	25.84	2.681	**0.022**	1.29

R_1- first race, R_2- second race, HR_{rest}- heart rate rest, HR_{max}- heart rate max, * - level of HR_{max}, Speed max - maximal speed during a race, Speed avg - average speed during a race, Cadence - revolutions per minute, Sprint - running for 1 sec. above (25.2 km/h).

Table 3 present correlations between specific physiological characteristics achieved in laboratory (VO_{2max}, VCO_{2max}, O_2P, PO) and the characteristics obtained during the MX races (HR_{rest}, HR_{max}, HR (70-80%), HR (80-90%), HR (90-100%), $Speed_{max}$, $Speed_{avg}$, Cadence, Sprints). Taking into account the results obtained in the R1 with the results obtained in the laboratory, it was found that, there were strong and significant negative correlations between HR_{rest} with PO ($r = 0.999$, $p<0.001$), as well as negative correlation between HR_{rest} and PO ($r = 0.897$, $p<0.001$) in the group G_1.

Table 4 contains differences in serum lactate concentration between G_1 and G_2, after R_1 and after R_2. There were no statistically significant differences in the serum lactate levels between G_1 and G_2 before the R_1 and R_2 races (> 0.05). After the R_1 and R_2 delta lactate showed no statistically significant difference between G_1 and G_2 [$t(12) = 2.074$, $p = 0.086$, and $t(12) = (-1.036)$, $p = 0.329$, respectively]. In the G_1 group, the concentration of SLL was significantly higher (by 3.8 mmol/L, $p = 0.028$) after the R_1, while there were no significant differences in SLL values before and after R_2. In the G_2 group, the differences in SLL concentrations before and after R_1 were on the borderline of significance ($p = 0.053$) at 1.8 mmol/L. As in the G_1 group, there were no significant differences in SLL before and after R_2 in the G_2 group. The quantitative values of SLL were also lower in both groups after second race (Table 4).

Table 3. Relationship between physiological characteristics measured in the laboratory and on the field (first and second races

Race	Groups	Characteristics		HR_{rest}	HR_{max}	HR 70-80%	HR 80-90%	HR 90-100%	Speed max	Speed avg	Cadence	Sprints
First (R_1)	G_1 (n=5)	VO_{2max} (mL/min/kg)	r	-0.102	-0.911*	-0.584	0.596	-0.570	-0.435	-0.303	-0.232	0.111
			p	0.870	0.032	0.302	0.289	0.315	0.464	0.62	0.708	0.859
		VCO_{2max} (mL/min/kg)	r	-0.269	-0.806	-0.384	0.437	-0.391	-0.354	-0.254	-0.084	0.037
			p	0.662	0.183	0.524	0.462	0.516	0.559	0.68	0.893	0.953
		O_2P (bpm)	r	-0.975**	-0.035	0.574	0.139	-0.013	0.442	0.305	0.549	0.082
			p	0.005	0.956	0.311	0.824	0.983	0.456	0.618	0.338	0.895
		PO (W)	r	**-0.999****	-0.011	0.595	0.046	0.099	0.329	0.169	0.475	-0.097
			p	**<0.001**	0.986	0.29	0.942	0.874	0.588	0.785	0.425	0.876
	G_2 (n=9)	VO_{2max} (mL/min/kg)	r	-0.423	0.075	-0.493	-0.408	0.542	-0.305	0.224	-0.155	0.186
			p	0.256	0.847	0.178	0.275	0.132	0.424	0.562	0.690	0.631
		VCO_{2max} (mL/min/kg)	r	-0.636	-0.120	-0.371	-0.215	0.429	-0.459	0.222	-0.257	0.224
			p	0.065	0.758	0.325	0.579	0.249	0.214	0.567	0.505	0.562
		O_2P (bpm)	r	0.125	0.023	-0.673*	-0.406	0.549	0.460	0.538	-0.005	-0.343
			p	0.749	0.953	0.047	0.278	0.126	0.213	0.135	0.990	0.366
		PO (W)	r	-0.472	-0.319	-0.326	-0.165	0.288	-0.220	0.310	-0.437	0.025
			p	0.200	0.403	0.393	0.671	0.452	0.570	0.417	0.240	0.950
Second (R_2)	G_1 (n=5)	VO_{2max} (mL/min/kg)	r	-0.107	-0.478	0.299	0.853**	-0.662	-0.238	-0.458	0.059	-0.499
			p	0.652	0.416	0.625	0.005	0.223	0.700	0.438	0.925	0.393
		VCO_{2max} (mL/min/kg)	r	-0.269	-0.453	0.541*	0.839	-0.588	-0.035	-0.405	0.135	-0.550
			p	0.563	0.443	0.035	0.075	0.297	0.955	0.498	0.829	0.337
		O_2P (bpm)	r	-0.875**	-0.680	0.005	0.386	-0.412	0.597	-0.595	0.633	0.088
			p	0.005	0.207	0.388	0.522	0.491	0.287	0.290	0.252	0.889
		PO (W)	r	**-0.897****	-0.643	0.457	0.407	-0.390	0.575	-0.553	0.502	-0.005
			p	<0.001	0.241	0.439	0.497	0.516	0.310	0.333	0.389	0.922
	G_2 (n=9)	VO_{2max} (mL/min/kg)	r	-0.383	0.128	0.545	0.284	0.057	-0.345	-0.449	-0.142	0.093
			p	0.282	0.743	0.129	0.459	0.884	0.363	0.226	0.716	0.813
		VCO_{2max} (mL/min/kg)	r	-0.537	-0.072	0.647**	0.441	-0.171	-0.470	-0.602	-0.369	0.122
			p	0.069	0.853	0.005	0.235	0.660	0.202	0.086	0.328	0.754
		O_2P (bpm)	r	0.226	0.151	-0.093	-0.379	0.499	0.307	0.306	0.590	-0.385
			p	0.568	0.698	0.812	0.315	0.172	0.421	0.424	0.094	0.306
		PO (W)	r	-0.371	-0.325	0.471	0.465	-0.094	-0.329	-0.326	-0.148	-0.171
			p	0.200	0.393	0.200	0.207	0.810	0.387	0.392	0.704	0.659

Bold numbers – strong correlations and significant differences ($p<0.004$) Bonferroni correction, the data on the horizontal axis are the same as in table 2, VO_{2max} - aerobic capacity (l/perc), VCO_{2max} - accumulated carbon dioxid (l/perc), O_2P - oxigen pulse (beat /ml), PO - power output.

Table 4. Differences between before and after serum lactate levels in each group (G_1 and G_2) and each race (R_1 and R_2).

MX groups	First Race (R_1)					Secund race (R_2)				
	SLL before (mmol/L)	SLL after (mmol/L)	QD (mmol/L)	t	p	SLL before (mmol/L)	SLL after (mmol/L)	QD (mmol/L)	t	p
G_1	1.62±0.43	5.44±0.65	3.82	2.552	0.028	1.78±0.49	4.72±0.51	2.94	1.560	0.149
G_2	1.51±0.60	4.74±0.60	3.23	1.843	0.053	1.73±0.59	4.87±0.71	3.13	1.761	0.108

SLL – serum lactate levels, QD – quantitative difference

DISCUSSION

The anthropometric and physiological profiles of young MX riders of varying ranks were assessed respectively with regard to anthropometric and body composition characteristics as well as physiological characteristics.

A comparative analysis of the results obtained directly during the races (R_1 and R_2) indicated a significant advantage for MX riders with international ranking, which manifested itself in a significantly shorter time per lap on average. In terms of anthropometric characteristics MX riders with international ranking were significantly superior to their peers with a national ranking only in terms of percentage of muscle mass (MMP). As indicated in numerous studies, based on road and MX riders the body mass and size is considered influential to riding performance [1,16,17]. D'Artibale et al. [4] additionally state that the final mass of the rider-motorcycle combination affects the engine power-to-weight ratio and consequently the ability to obtain high acceleration (reaching higher top speed before the next turn). The present study, however, focused on relatively young MX-riders and showed that in motocross races the percentage of muscle mass instead of total body mass (which also included body fat) was significantly higher in riders with an international ranking and thus achieving better and more prestigious results in MX races. In contrast, the lack of significant differences in mean body mass values between G_1 and G_2 confirms our assumptions that MMP plays a more important role than total BM and is a determinant of MX performance among young riders. In a study by Gobbi et al. [2], the BM of the motocross and enduro riders was found to be in the higher range of normal values, while desert rally riders tended to be overweight. Generally, in motorsports, being overweight is unfavorable because it overloads the MX motorbike as well as provides extra mass that must be accelerated (and decelerated during braking). Therefore, the heavier rider requires more muscular force for optimal motorcycle control [2,3,5-8]. From the physiological point of view, fat mass is negatively associated with the physiological ability of the tissue to consume oxygen [18]. Moreover, VO_2 during weight-bearing exercise performed at the same submaximal work rate is higher for riders with excessive muscle mass [19]. In the future, therefore, a preferred MMP standard should be created for young MX riders.

Starting training and competitions at a young age can help to increase the training age, which is vital for children and adolescents whose motor skills are highly "plastic" and sensitive to training [22]. Presumably, this is also an important element in the differences in competitive performance between the two groups [23].

During the first race (MX) readers from G_1 were in the effort intensity range of HR (90-100%) for a significantly longer period of time and reached higher top speed max than the representatives of G_2. Surprisingly, during the second race, (MX) riders from G_2 stayed significantly longer in terms of effort intensity range HR (90-100%) and significantly lower distance of sprints, but no significant differences in the speed max were found. It is therefore reasonable to assume that MX riders with national ranking (G_2) exerted a significantly greater effort during R_2 than riders with international ranking, which did not contribute significantly to riding speed. Circulatory characteristics measured in the laboratory did not differ significantly between G_1 and G_2.

It is important to note, that race performance is mainly conducted in the range determined between VT and RCP that can exactly be identified by the measured intensity zones recorded by Polar Team Pro device. From Table 1 data it can be calculated that VT/MP equals 88,8% and RCP/ MP equals 94%. This is equal to the time spent in the intensity zones [5, 6] indicated in Table 2. It can be said that in both races the runners crossed the anaerobic threshold several times, and in several cases spent a long time in this range (HR (90-100%)=713.4 sec in the first race compared to 843.5 sec in the second race). This is close to ~60% of the total race for a 20 min race. The lack of significant differences in serum lactate levels (SLL) between G_1 and G_2 suggests that the representatives of both groups began the MX races (and thus the physical efforts) from basically the same level. Moreover, the concentration of SLL did not differ significantly in the same configuration after the R_1 and R_2 races. The lack of significant differences in SLL between the study groups may suggest that their representatives performed similar physical efforts during R_1 and R_2 and revealed a similar physiological response to exercise stress.

In the G_1 group, the concentration of SLL was significantly higher o 3.8 mmol/L after the R_1, while there were no significant differences in SLL values before and after R_2. In the G_2 group, the differences in SLL concentrations before and after R_1 were on the borderline of significance at 1.8 mmol/L, In the case of R_2, however, there was a similar situation to that in G_1. Konttinen et al. [20] described in their study that the average VO_2 exceeds (90-94%) of the maximum value. During motor exercise, relative aerobic capacity VO2 was correlated with forward speed ($r = 0.70$, $p < 0.01$). Heart rate (HR) remained at (97-98%) of the maximum value. The mean blood lactate concentration (5.4±0.65) mmol/l measured in the present study was lower than the 6-8 mmol/l reported by von Lehmann et al. [21] and was also much higher than the 1.0 mmol/l reported by Collins et al. [9]. The physical strain comes from the handling of the engine, which is a result of the unevenness of the track and the struggle of the riders. Our data suggest that motocross represents a real physiological and neuromuscular strain, the analysis of which is a particularly important task for professionals involved in the sport.

Strength and Limitations

The strengths of this research constitute relatively young MX drivers who are already spectacularly successful at major sporting events. The major limitation of our study is that we do not have VO_2 data from the races. In previous literature [3] they reported a $\%VO_{2max}$ during a field test (riding a motocross track). This limitation is understandable as it would be "impossible" to expect these riders to wear a portable metabolic system while racing. A further limitation of our study is that the HR values measured in the laboratory differed from the HR data recorded in the races, but HR zones were set according to the laboratory-measured values. Moreover, we were not able to obtain VO_2 data during the races because we did not have a mobile spiroergometric device designed for this purpose, and because the rules of the motocross sports federation do not allow competitors to wear any device that could cause injury in the event of a fall during a race.

CONCLUSION

Current results show that motocross puts a great physical strain on riders during races. Motocross riders, therefore, need to have a high level of motor fitness to maintain the best possible position on the track. We did not found significant differences between the two groups' antropometric and physiological characteristics except muscle mass percentage (MMP%). The achievement of significantly higher speedmax and sprint values during races by internationally ranked MX riders is probably due to their having better technical skills regarding the steering of the motorbike than nationally ranked MX riders. The results obtained by the G_1 and G_2 representatives during the motor tests and anthropometric measurements in the laboratory (no significant differences), confronted with the results obtained directly in the two races, show a significant advantage for MX riders with international ranking in terms of a significantly shorter average lap time. Motocross is a sport that involves high physical exertion and demands both the mental skill and physiological capacity of the rider

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