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The Effect of Different Motocross Circuit Typologies on Internal Load and External Load Responses in Riders

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ABSTRACT

Background: Several physical and physiological changes occur during a motocross race, mainly due to the type of circuits, and therefore the impact of different types of circuits on training load responses continues to need to be fully clarified. **Objective:** The main aim of the present study was to compare the internal load and external load responses of motocross riders from different classes and on circuits of different types. **Method:** A quasi experimental design research was used in the study.The sample consisted of 10 motocross riders (28.10 ± 7.53 years; 74.60 ± 9.70 kg; 176.50 ± 7.18 cm; 23.88 ± 2.18 BMI), male., distributed by the Mx Elite and Mx Hobby categories. The pilots were evaluated before and after the race in relation to indicators of external load (accelerations and decelerations, maximum speed and average speed and impacts) and internal load (Heart rate, blood lactate and rating of perceived exertion) on two circuits of different types. **Results:** There was a trend towards higher internal load responses in the Mx Hobby class compared to the Mx Elite class ($p \leq 0.05$), regardless of the circuit. Regarding external load responses, the Mx Hobby class has a tendency towards higher maximum and average speeds, while the Mx Elite class presents the same tendency for accelerations and decelerations. **Conclusions:** Different circuit types appear to influence pilots' internal load and external load responses.

Key words: Human Body, Activity; Motor, Skills, Loads, Variability

INTRODUCTION

Motorcycling is a sport that encompasses several disciplines, such as motocross, enduro, off-road, supercross, and speed, among others (Ascensão et al., 2008). These modalities are played on hard ground or sand terrain, with a predominance of jumps, steep slopes, tight curves and mud (Ascensão et al., 2008; Konttinen et al., 2007).

Motocross is characterized as a competitive form of off-road motorsports that is contested. Regardless of the class in which the riders are included, everyone aims to improve their physical preparation, as it is considered essential for achieving significant results (Ascensão et al., 2008). Riders require control of the motorcycle in terms of speed, reacting immediately to sudden movements it may make (Ascensão et al., 2008). Therefore, it is necessary to have skill, muscular strength and resistance (Ascensão et al., 2008). Likewise, the type and duration of tests and training, combined with the type of equipment and protection used by pilots, increase their physiological demands and their level of psychological stress in this modality (Beaumont et al., 2023). According to Tomida et al. (2005), pilots run more offensively during timed races to obtain better starting positions, which together with the equipment and protections used increase body temperature, resulting in increased heart rate (HR). Furthermore, in a motocross race, it is common for repetitive isometric contractions to occur, essentially of the muscles of the upper limbs, since the left hand is always used to manipulate the clutch and the right hand is always used to use the accelerator and front brake (Carraro et al., 2014). Also, Ascensão et al. (2008) reported that the most required muscles

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are those of the upper limbs and lower limbs in conjunction with balance and cardiovascular work. In both amateur and professional pilots, there is a high demand on the limbs mentioned above, but in some cases caused by the technique of some pilots, which can modify the percentage of limb use (Konttinen et al., 2008). This also leads to increased HR, blood pressure and blood lactate levels (Simões et al., 2016). In motocross, HR is generally above 80% of maximum and remains at high levels during the race (Gobbi et al., 2005). This allows us to understand the rider's load and his autonomous response to the complexity and variation of both the race environment and track conditions, the position of the bike, overtaking, acceleration or braking (Corcoba-Magaña et al., 2017).

During a motocross race, there is inevitably a gradual increase in fatigue due to the stress imposed by the race, which results in an increase in lactate concentration (Gobbi et al., 2005). Cadwell and Rauhala (1983) recommend training aimed at developing aerobic capacity and some specific exercises for the technical manoeuvres that the modality requires. Konttinen et al. (2008) reported that the physiological demands during a motocross race are similar to Sky Country practitioners as it is an endurance event requiring a high aerobic metabolism level. In this modality, the static involvement of several muscle groups in conjunction with jumping and landing actions leads to the origin of fatigue, thus causing a decrease in the muscular strength required to accelerate the motorcycle's engine during the race (Gobbi et al., 2005). Consequently, this effect can restrict competitive performance in motocross as in other motorsports. Additionally, it is also important to note that increased levels of fatigue increase the risk of accidents and injuries (Simões et al., 2016). The concentration of blood lactate increases considerably between 10 and 20 minutes after running (Ascensão et al., 2008). According to Burr et al. (2010), high lactate levels prove that aerobic exercise is predominantly performed when running off-road vehicles. Another factor that can negatively influence pilots' performance is dehydration, that is, heat is generated throughout the race throughout the race and this needs to be dissipated to maintain body temperature (Powers et al., 2014). Therefore, heat dissipation can lead to dehydration and compromise pilot performance (Powers et al., 2014). Performance in this modality depends considerably on the driver's ability to distribute his body mass in an opportune manner, depending on the characteristics and conditions of the circuit (D'Aitibale et al., 2007). Therefore, it is possible to state that the physiological effort during motocross races is considerable, as they have muscular, cardiovascular, metabolic and hormonal components that must be taken into consideration (Konttinen et al., 2007).

Based on information developed in various sports, external load variables have been observed through competitive demands (Coutts et al., 2017). According to Coutts (2016), external load can be classified into three categories, namely mechanics, which assesses muscular need during exercise, kinematics, which determines displacements during exercise, and metabolic, which indirectly assesses the energy expended. during exercise. With these data, it is possible to analyse some external load variables, more specifically acceleration and deceleration, distance travelled and impacts at different intensities (Martín-García et al., 2018).

Based on the literature, several physiological changes occur during a motocross race, mainly due to the type of circuits, and therefore this issue continues to need to be fully clarified. In this regard, literature continues to be scarce, especially with regard to studies that seek to clarify the physical and/or physiological responses of motocross riders according to the different categories/classes of riders, also taking into account different circuit typologies. Thus, the main aim of the present study was to compare the internal load and external load responses of motocross riders from different classes and on circuits of different types. We hypothesize that different driver classes and different circuit typologies lead to significantly different internal and external load responses.

METHODS

Participants and Study Design

The study used a quasi-experimental research design.The sample consisted of 10 motocross riders (28.10 ± 7.53 years; 74.60 ± 9.70 kg; 176.50 ± 7.18 cm; 23.88 ± 2.18 BMI), male, distributed across the Mx Elite and Mx Hobby (Table 1), participants in the Pentacontrol Mx Portuguese Regional Championship. All pilots participated in the study voluntarily, using their own motorcycles and safety equipment required in official competitions. Pilots who tested positive for Covid-19 and all those who did not perform the two tests analysed were excluded from the study. All participants were informed about the genesis and requirements of the study, having answered a questionnaire about their health history, which mentioned the associated risks, and the possibility of abandoning the research even after it had started. All procedures were carried out in accordance with the guidelines of the Declaration of Helsinki for investigations in humans, the study was approved by the ethics committee of the Research Center in Sports Sciences, Health Sciences and Human Development (CIDESD).

Circuit Characterization

The configurations and dimensions of the circuits are a factor that can influence the drivers' performance during the race, for this reason Table 2 presents the characterization of the tracks that were involved in the study.

Procedures

The riders (considered the independent variable) participated in two motocross events (i.e., timed training session) in natural environmental conditions, sunny during spring with temperatures around 24 degrees celsius. Before the start of timed training, all pilots were reminded of the procedures and at that time anthropometric data were collected. Before the start of timed training, blood lactate concentration was collected and it was checked whether the technological tracking system and the respective heart rate meters

Table 1. Sample characterization

Class	Age (years)	Weight (kg)	Height (cm)	BMI (%)
Mx Elite	31.5 ± 8.96	73.5 ± 3.70	177.5 ± 5.26	23.35 ± 1.21
Mx Hobby	25.83 ± 6.21	75.33 ± 12.63	175.83 ± 8.66	24.23 ± 2.70

Table 2. Circuit characterization

Typology	Circuit 1	Circuit 2
Ground	Hard floor	Hard floor and sand
Distance	1600 meters	1600 meters
Number of curves	14	12
Number and jump typology		
Rollers	6	15
Step off	0	3
Double	1	3
Table	5	0
Whoops	1 (formed by 5 waves)	0

were well placed to start collecting external load indicators (accelerations and decelerations, maximum speed and average speed and impacts) and internal load (HR) respectively (both considered dependent variables). After the end of the race, the blood lactate concentration was collected again and the subjective perception of effort was measured according to the Borg Scale (10 points). These indicators were chosen because they are crucial for evaluating performance in motocross.

Anthropometric Data

To measure anthropometric data, the pilots were weighed on a digital scale (TRISTAR) and measured using a measuring tape. After this moment and considering their age, each individual's Body Mass Index (BMI) was calculated using the formula Weight (kg)/height2 (m) (Orellana-Lepe et al., 2023).

Internal Load

Lactate

Blood lactate concentration (mmol/L) was measured using a portable lactate meter Lactate Pro 2 (AKRAY Europe B. V. Prof J.H Bavincklaan 5 1183 AT, Amstelveen, the Netherlands). The first drop of blood was discarded to avoid contamination with sweat and, shortly afterwards, a blood sample was collected through the fingertips and inserted into the device, before and after the timed workouts. The Lactate Pro 2 meter has a measurement range between 0.5-25.0 mmol/L (Raa et al., 2020).

Heart rate

The average HR (bpm) and maximum HR were recorded using a GARMIN HRM-PRO (Garmin Ltd) placed on a chest strap, located below the chest and in direct contact with the body. These data were exported using the WIMU SPRO software (Realtrack Systems SL, Almeria, Spain).

Rate of perceived exertion

Rate of Perceived Exertion (RPE) was measured at the end of the race using the Borg Scale with ratings ranging from 0-10, where 0 corresponds to no effort and 10 maximum effort (Borg, 1954).

External Load

The pilots' activity was measured using an ultra-wide-band tracking technology system from WIMU PROTM (Realtrack Systems, Almeria, Spain) under the equipment.

Data from the beginning to the end of the race were analysed using the SPRO software (Realtrack Systems SL, Almeria, Spain). From this data, variables were extracted based on two categories of external load, more specifically kinematic (maximum and average speed) and mechanics (accelerations, decelerations and impacts).

Statistical Procedures

Initially, descriptive statistics of the variables under study were prepared, later the normality of the sample was verified using the Shapiro-Wilk test ($n \leq 30$). The mean and standard deviation were calculated for each of the variables analysed in each of the circuits. Statistical significance was measured using T tests for paired and independent samples (i.e., intra and inter sample), the Wilcoxon equivalent test was applied to variables that did not follow the assumption of normality. The percentage differences between the analysed circuits were calculated using an equation (Branquinho et al., 2020). Effect sizes were calculated based on Cohen's d and classified as 0.2 - trivial; 0.6 – small; 1.2 - large; and >2.0 – very large (Hopkins et al., 2009). Statistical analyses were performed with 95% CI; $p < 0.05$. All procedures were performed with SPSS version 24.0 (SPSS, Inc., Chicago, IL, USA).

RESULTS

The results of the comparison between averages for the two circuits analyzed in the Mx Elite class are presented in Table 3. Significant differences were found with a very large effect in the comparison for the external load variable Impacts. Although no statistically significant differences were found for the variables accelerations, decelerations, Max speed and Med speed, there seems to be a tendency for lower responses in circuit 1 compared to circuit 2. In reverse, it looks like there is a tendency for higher internal load responses in Circuit 1 compared to Circuit 2. These data follow the trend seen in the RPE where significant differences with a large effect were found between Circuit 1 and Circuit 2. Even so, no differences were found for blood lactate concentration between circuits $p \geq 0.05$. Thus, there appears to be a tendency towards higher values of training load in circuit 2 and higher internal load in circuit 1, except for lactate.

Table 4 presents the comparison between averages between the two circuits analysed in the Mx Hobby class. The results indicate the existence of statistically significant differences with a very large effect, in all external load variables except for Max Speed. The internal load variables (i.e., HR Max, Avg HR and [LA] (BR and AR)) did not present significant differences in the comparison made $p \geq 0.05$, while significant differences of very large effect were found for RPE.

Table 5 presents the comparison between means between the two classes analysed (i.e., Mx Elite and Mx Hobby) in relation to performance in circuit 1. The results indicate the existence of significant differences for the external load variables Accelerations, Decelerations and Average Speed with very large, large and very large effects respectively. Regarding the internal load variables, only Avg HR and RPE showed significant differences with a very large effect.

Finally, Table 6 reports the comparison between means between the two classes analysed (i.e., Mx Elite and Mx Hobby) in relation to performance in circuit 2. The results indicate that significant differences were found with a very large effect, only for the variable Impacts.

DISCUSSION

The main aim of this work was to compare the internal load and external load responses of motocross riders from different classes (Mx Elite and Mx Hobby) and on circuits of different types. The results revealed a trend towards higher internal load responses in the Mx Hobby class compared to the Mx Elite class regardless of the circuit. Regarding external load responses, the Mx Hobby class presents higher values of maximum and average speed, while the Mx Elite class registers higher values of accelerations and decelerations. Furthermore, in the comparison made between circuits (circuit 1 vs. circuit 2), there is a tendency for higher internal load responses for both classes in circuit 1, apart from heart rate in the Mx Hobby class where higher responses Elevated responses were found in circuit 2. Regarding external load, circuit 2 appears to induce higher responses in all variables analysed in both classes, except for impacts.

The comparison between the two classes allows us to conclude that the internal load responses tend to be lower in the Mx Elite compared to the Mx Hobby. One of the indicators that stands out due to the difference in internal load responses between the two classes is the level of lactate in the blood after running, in which its accumulation is related to the fatigue that generally occurs in more demanding exercises. In this modality, fatigue is mainly caused by isometric contractions of various muscle groups, together with jumping and landing movements. According to the study by Simões et al. (2016), the lactate concentration values after a motocross race are considerably high, showing a decrease in muscle strength as a result of the isometric contractions frequently performed to control the bike. Simões et al. (2016) also report that this constant activity significantly causes fatigue in the flexor muscles that control the fingers and wrist, reducing strength in both hands. Elite riders are more professional than Hobby riders, since to race in this category they need to have scored points in national Mx, national Enduro, Super Enduro or Enduro Sprint races in the previous season. In fact, these races are more demanding compared to the regional ones, that is, the pilots have a much more improved and demanding physical preparation (physical training in the gym, training on the track) and can be more controlled in psychological terms, not being as susceptible to stress. According to Cruz (1996), elite athletes have better psychological skills, namely self-confidence and experience lower levels of competitive anxiety. On the other hand, Mx Hobby riders can be more affected by psychological factors, from a less successful start, a fall, a puncture or even competition with the remaining participants can influence the continuity of the race. Furthermore, the different engine sizes of motorcycles can influence the physical effort during riding. Each motorcycle has a mass of between 85 and 115 kilo-

Table 3. Sample characterization

	Class		T-test			Cohen's d
	Mx Elite		*Δ (%)*	*p*	*d*	Classification
	Circuit 1	Circuit 2				
Accelerations (n)	104.71 ± 40.55	148. 82 ± 35.99	42.12	0.136	1.15	Large
Decelerations (n)	101.73 ± 39.53	148,33 ± 34.96	45.80	0.088	1.24	Large
Max Speed ($m{\cdot}s^{-1}$)	31.17 ± 2.32	34.77 ± 6.63	11.54	0.336	0.72	Small
Avg Speed ($m{\cdot}s^{-1}$)	13.16 ± 2.58	16.56 ± 3.44	25.83	0.114	1.11	Large
Impacts (n)	6558.25 ± 1398.10	1398.0 ± 66.69	-78,68	0.001**	5.21	Very large
HR Max (bpm)	189.50 ± 2.64	171.16 ± 31.41	-9.70	0.287	0.82	Small
Avg HR (bpm)	167.25 ± 7.41	144.83 ± 40.84	-13.39	0.318	0.76	Small
[LA] - (BR) (mmol/L)	2.1 ± 0.57	1.98 ± 0.66	-5.71	0.670	0.19	Small
[LA] - (AR) (mmol/L)	9.4 ± 1.57	7.1 ± 3.54	-24,46	0.394	0.83	Small
RPE (borg scale)	7.75 ± 0.50	6.16 ± 1.16	-20.51	0.036*	1.78	Large

LA – Blood lactate concentration; BR - *Before Race*; AR - *After Race*; * = < 0.05; ** = <0.01

Table 4. Average differences between circuit 1 and circuit 2 in the Mx Hobby class

	Class		T-test			Cohen's d
	Mx *Hobby*		*Δ (%)*	*p*	*d*	
	Circuit 1	Circuit 2				
Accelerations (n)	40,80 ± 16.19	140.66 ± 9.86	244.67	0.025*	7.34	Very large
Decelerations (n)	40,00 ± 16.38	140.33 ± 5.85	250,82	0.025*	8.15	Very large
Max Speed ($m\cdot s^{-1}$)	33.39 ± 4.69	38.43 ± 0.24	15.09	0.122	1.51	Large
Avg Speed ($m\cdot s^{-1}$)	17.15 ± 0.875	20.74 ± 0.330	20.93	0.036*	5.42	Very large
Impacts (n)	6687.20 ± 2728,1	1595,66 ± 84.80	-76.13	0.020*	2.63	Very large
HR Max (bpm)	193.80 ± 6.05	199.33 ± 1.52	2.85	0.182	1.25	Large
Avg HR (bpm)	182.0 ± 3.60	184.33 ± 2.30	1.26	0.361	0.77	Small
[LA] - (BR) (mmol/L)	3.1 ± 0.59	2.1 ± 0.73	-32.25	0.101	1.50	Large
[LA] - (AR) (mmol/L)	15.0 ± 3.64	11.4 ± 3.84	-24.00	0.101	0.96	Small
RPE (borg scale)	8.80 ± 0.44	7.66 ± 0.57	-12.95	0.020*	2.23	Very Large

LA - Blood lactate concentration; BR - *Before Race*; AR - *After Race*; * = < 0.05; ** = <0.01

Table 5. Average differences between the Mx Elite and Mx Hobby Classes on circuit 1

	Class		T-test			Cohen's d
	Circuit 1		*Δ (%)*	*p*	*d*	
	Mx Elite	Mx Hobby				
Accelerations (n)	104.71 ± 40.55	40,80 ± 16.19	- 61.03	0.037*	2.07	Very large
Decelerations (n)	101.73 ± 39.53	40,00 ± 16.38	- 60.68	0.050*	1.99	Large
Max Speed ($m\cdot s^{-1}$)	31.17 ± 2.32	33.39 ± 4.69	7.12	0.420	0.60	Small
Avg Speed ($m\cdot s^{-1}$)	17.15 ± 0.875	20.74 ± 0.330	20.93	0.014*	5.42	Very Large
Impacts (n)	6558.25 ± 1398,16	6687.20 ± 2728.14	1.96	0.934	0.05	Trivial
HR Max (bpm)	189.50 ± 2.64	193.80 ± 6.05	2.26	0.232	0.92	Small
Avg HR (bpm)	167.25 ± 7.41	182.00 ± 3.60	8.81	0.006**	2.53	Very large
[LA] - (BR) (mmol/L)	2.1 ± 0.57	3.1 ± 0.59	47.61	0.065	1.72	Large
[LA] - (AR) (mmol/L)	9.4 ± 1.57	15.02 ± 3.64	59,78	0.086	2.06	Very Large
RPE (borg scale)	7.75 ± 0.50	8.8 ± 0.44	13.54	0.013*	2.22	Very Large

LA - Blood lactate concentration; BR - *Before Race*; AR - *After Race*; * = < 0.05; ** = <0.01

Table 6. Average differences between the Mx Elite and Mx Hobby Classes on circuit 2

	Class		T-test			Cohen's d
	Circuit 2		*Δ (%)*	*p*	*d*	
	Mx Elite	Mx Hobby				
Accelerations (n)	148. 82 ± 35.99	140.66 ± 9.86	- 5.48	0.606	0.30	Trivial
Decelerations (n)	148,33 ± 34.96	140.33 ± 5.85	- 5.39	0.506	0.31	Trivial
Max Speed ($m\cdot s^{-1}$)	34.77 ± 6.63	38.43 ± 0.24	10.52	0.386	0.78	Small
Avg Speed ($m\cdot s^{-1}$)	16.56 ± 3.44	20.74 ± 0.330	25.24	0.071	1.71	Large
Impacts (n)	1398.0 ± 66.69	1595.66 ± 84.80	14.13	0.006*	2.59	Very large
HR Max (bpm)	171,16 ± 31,41	199.33 ± 1.52	16.45	0.117	1.26	Large
Avg HR (bpm)	144.83 ± 40.84	184.33 ± 2.30	27.27	0.150	1.36	Large
[LA] - (BR) (mmol/L)	1.98 ± 0.66	2.16 ± 0.73	9.09	0.796	0.25	Trivial
[LA] - (AR) (mmol/L)	7.18 ± 3.54	11.4 ± 3.84	58.77	0.071	1.14	Small
RPE (borg scale)	6.16 ± 1.16	7.66 ± 0.57	24.35	0.080	1.64	Large

LA Blood lactate concentration; BR - *Before Race*; AR - *After Race*; * = < 0.05; ** = <0.01

grams, which can make a big difference, as the greater the mass, the more difficult the rider's work will be in terms of rapid changes of direction and maximum use of the energy produced by the engine, interfering with the ability to reach higher speeds faster (Wilson, 2019).

In addition, it is possible to observe that the Mx Elite has superior acceleration and deceleration responses than the Mx Hobby and, on the other hand, the MX Hobby has lower maximum speed and average speed responses. No scientific studies were found that compared these indicators in two different classes, however the results indicate that during the races, elite pilots have more experience in approaching the actions carried out during the race, taking advantage of all the small details to improve their lap. On the other hand, those from Hobby tend to compensate on the straights to generate some advantage in their times, since they are more inexperienced in cornering, thus obtaining a higher value in average speed. It was possible to observe that the elite drivers made some stops during the route to check the lap times completed and the position they occupy, as well as the position and time of the other drivers, to understand if there is a need and possibility to improve lap time, as the objective of timed training is to achieve the best time in a lap. In turn, the Mx Hobby riders did not make stops, as compared to the elite, they are not so interested in the place they will occupy on the grid, but rather in the dispute with the remaining participants. These types of actions or even some technical problem seem to have influenced the average speed.

According to the results and comparing the circuits, it was possible to verify that the Mx Elite and Mx Hobby categories obtained higher internal load responses in circuit 1, except for HR, which was higher in circuit 2 in the Mx Hobby class. The divergence of both circuits can explain this difference in responses, since circuit 1 presents greater difficulty and demands due to the types of jumps, the greater number of curves and the shorter straights compared to circuit 2. Regarding the HR (i.e., max and avg), riders in the Mx Hobby class are more physically and technically adapted to circuit 1 as it is the place where they usually carry out most of their training. In this way, it can be accepted that higher HR responses can be obtained in circuit 2, which are caused by adaptation to the terrain and the more demanding technique. Another factor that may influence the results found for this indicator is the positioning of the riders on top of the motorcycle, that is, they are mostly raised up (only with their feet on the skates) during the race and use the motorcycle seat more to perform the tasks. curves. This allows the motorcycle to have more traction and reach higher speeds, giving riders greater control and stability, although it is a more demanding position from a physical point of view. Furthermore, terrain irregularities, bike stabilisation, and sudden changes in direction require numerous isometric contractions, which could also explain the riders' high HR during the race. According to the study by Gobbi et al. (2005) and corroborating the results found, the HR is usually above 80% of maximum and remains at very high internal load responses during the race, with a tendency to increase during the more complex parts of the circuit. Gobbi et al. (2005), also compared motocross with enduro and confirmed the greater demand of motocross where the HR was relatively lower in enduro, presenting values between 20 and 50% of the maximum HR.

Regarding external load responses, the difference in impact responses in both circuits is evident. Circuit 1 presents a type of jump, called a table jump, which is more demanding than the other jumps on the track as it requires more flight time to be executed well, and for this it is necessary to have the right acceleration when performing it and has a greater impact on the ground at the time of landing. On the other hand, the jumps on circuit 2 are mostly shorter and quicker to perform, which leads to fewer impacts. This circuit has a greater number of straights and longer distances, making it useful for riders to accelerate their bikes and increase their speed until the curve where they need to slow down to be able to execute it. In this way, higher external load responses of accelerations, decelerations and speed are seen in circuit 2. According to a study on Enduro Mountain Bike by Kirkwood et al. (2017), the type of terrain significantly changes the profile of the circuit. Indeed, the athlete's load profile showed that technical terrain results in significantly longer time in higher load zones when compared to non-technical terrain, although average speed is higher on non-technical terrain (Kirkwood et al., 2017).

This investigation is not without limitations, including the small sample size, that is, if the number of pilots were greater there would be less possibility of stoppages or other types of technical problems occurring. In the future, more types of circuits and a greater number of riders should be analysed to detect load profiles and understand which indicators most highlight motocross rider load indicators.

CONCLUSION

The study allows us to conclude that motocross is a sport characterized by a high intensity of exercise that varies in different environments. It is challenging on both a physical and psychological level, imposing high physiological demands on several levels. The fatigue that this modality can cause must be considered during pilot training, as it causes a decrease in muscular strength to perform movements and control the bike during the race, as well as psychological wear and tear that causes a lack of attention and reaction, and consequently can affect performance, cause accidents and injuries. Pilots must adapt training according to their objectives, circuit and class, in order to improve the load-fatigue relationship process. The circuit distinctions seem to influence the drivers' internal load and external load responses, with structural differences existing between their behaviour on different types of circuits. Therefore, pilots must observe these indicators and understand their effects to improve performance. The results found in the present work allow us to contribute to a more effective pilot load control process, also serving as a basis for future research in this area.

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AUTHOR CONTRIBUTION

L.B. and R.F. conceptualized the study; The intervention methodology was defined by L.B. and R.F. L.B. and R.F. validated the study. J.R., L.B. and R.F performed the formal data analysis. J.R., L.B., P.F., N.V., A.S., J.E.T., and RF participated in the preparation of the original draft; Writing - review and editing was carried out by L.B., P.F., A.S. J.E.T., and R.F. The project was supervised and managed by L.B. and RF, which was also responsible for acquiring financing. All authors read and agreed to the published version of the manuscript.

ETHICAL APPROVAL

The study was approved by the scientific committee of the Research Center in Sports Sciences, Health Sciences and Human Development (CIDESD) and carried out in accordance with the guidelines of the Declaration of Helsinki for human research.

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