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# ORIGINAL

# CHRONOTROPIC AND CARDIAC AUTONOMIC RESPONSES IN SPEED MOTORCYCLING. A CASE STUDY

# RESPUESTA CRONOTRÓPICA Y CARDÍACA AUTÓNOMA EN MOTOCICLISMO. UN ESTUDIO DE CASO

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## ABSTRACT

The purpose of the present study was to analyze the chronotropic and cardiac autonomic response of a motorcyclist during the 7th race week of the FIM-CEV Repsol Moto2 European Championship through heart rate ($HR_{AVG}$) and sympathetic-parasympathetic ratio (RS-Ps). The effect and relationships of sessions, laps and track segments were analyzed by MANOVA test with Bonferroni post-hoc and Pearson's r. A low effect of the segments in RS-Ps ($p$<.01; $\omega_p^2$=0.03), and high effect of the sessions ($p$<.01; $\omega_p^2$=0.72), laps ($p$<.01; $\omega_p^2$=0.95) and the interaction between sessions and laps ($p$<.01; $\omega_p^2$=0.62) in $HR_{AVG}$ were found. Also, a tendency of increasing $HR_{AVG}$ was found with sessions ($r$=.315; $p$<0.01) and laps ($r$=.280; $p$<0.01). No significant correlations were found with RS-Ps. While $HR_{AVG}$ can be used as a fatigue index during motorcycling competition, RS-Ps indicates the significant rider's stress at specific segments of the track, being important both variables for improving the riders' performance.

**KEYWORDS**: Stress, heart rate, motorcycling, internal load

## RESUMEN

El objetivo del presente estudio fue analizar la respuesta cronotrópica y cardiaca autónoma de un piloto de motociclismo durante la 7ª prueba del Campeonato de Europa FIM-CEV Repsol Moto2 mediante frecuencia cardíaca media ($FC_{MEDIA}$) y ratio simpático-parasimpático (RS-Ps). El efecto y relaciones de las sesiones, vueltas y segmentos del circuito fue analizado mediante MANOVA con post-hoc Bonferroni y r de Pearson. Se encontró bajo efecto de los segmentos en RS-Ps ($p$<.01; $\omega_p^2$=0.03), y alto efecto de sesiones ($p$<.01; $\omega_p^2$=0.72), vueltas ($p$<.01; $\omega_p^2$=0.95) e interacción sesiones-vueltas ($p$<.01; $\omega_p^2$=0.62) en $FC_{MEDIA}$. Además, se hallo una tendencia de incremento de $FC_{MEDIA}$ respecto a sesiones ($r$=.315; $p$<.01) y vueltas ($r$=.280; $p$<.01). No se encontraron correlaciones significativas con RS-Ps. La $FC_{MEDIA}$ puede utilizarse como un indicador de fatiga durante la competición, mientras que el RS-Ps indicaría el estrés significativo del piloto en segmentos específicos del circuito, siendo ambas variables importantes para mejorar el rendimiento del piloto.

**PALABRAS CLAVE**: Estrés, frecuencia cardíaca, motociclismo, carga interna.

## 1. INTRODUCCIÓN

Currently, the measurement of the external and internal load of athletes, as well as the analysis of performance-related factors, are deemed important for the understanding of the dynamics of a specific sport (Bartlett et al., 2017; McLaren et al., 2018). Speed motorcycling is considered a sport with a high complexity since high speeds of the motorbike place noticeable stress on the athlete due to the imminent risk of accident or death (Jamson & Chorlton, 2009; Talib et al., 2015). For example, sudden braking actions, being associated in more than 40% of the cases with a starting speed greater than 260 km/h, cause accelerations greater than 10 m/s2 with a high body mechanical load (D'Artibale et al., 2018). This fact may be one of the reasons why a scientific approach to motorcycling has been conducted. Technological improvements have been carried out in the motorcycle, boosting performance and rider's safety, who now compete with better helmets, gloves and suits (Kim et al., 2018).

Only a few studies have focused on the rider as the main topic. The rider's analysis has been made based on contextual variables such as physical fitness (Gutierrez et al., 2002; Mateo-March et al., 2013; Rodríguez-Pérez et al., 2013), psychology (Gil Moreno de Mora, 2015; Mateo-March et al., 2013) and fatigue-recovery (Gil Moreno de Mora, 2015). Thus, the understanding of rider's internal response (e.g., heart rate) to motorcycling could enrich current literature and lead to the development of alternative training methodologies in terms of load prescription, nutritional plans or recovery protocols while considering the internal load (Morosi et al., 2015; Pino-Ortega et al., 2019).

In this sense, heart rate has been previously used as an internal load intensity indicator (Corcoba-Magaña et al., 2017; Sanna et al., 2017; Talib et al., 2015). This physiological indicator reflects the global physical load during sports practice so it increases while motorcycling due to physical and psychological exertion and fatigue (Corcoba-Magaña et al., 2017), speed, tracking or tracks (Corcoba-Magaña et al., 2017), as well as the prevalence of isometric contractions during the competition (Konttinen et al., 2007). In addition, heart rate variability can also be an indicator of stress in motorcycling (Corcoba-Magaña et al., 2017) which allows the understanding of the rider´s load and its autonomic response to the complexity, variation of race environment and conditions such as curves, position, leading, breaking, speed, and others.

Previous studies have reported that heart rate may reach 150 beats per minute (bpm) on average in competitive simulation tests of Enduro motorcycling (Sanna et al., 2017) or 168 bpm in Supermoto riders (Morosi et al., 2015). Also, non-competitive motorcycling seems to be less demanding since it requires an average of 105 bpm (Talib et al., 2015). However, these data cannot be extrapolated to speed motorcycling because of the differences between disciplines. Then, the lack of evidence in terms of rider's internal load analysis leads to the necessity of new approaches to speed motorcycling.

In recent years, the use of wearable sensors has facilitated real-time data collection about physical demands in both training and competition settings (Cummins et al., 2017). For example, inertial measurement units could be an example of how the use of telemetry allows the quantification of heart rate as a load indicator in a non-invasive way, without putting the rider into risky or vulnerable situations (Rojas-Valverde et al., 2019). Therefore, considering the autonomic responses produced during practice and competition, this study aims to investigate the chronotropic response through heart rate during a competitive week in speed motorcycling and its variation according to contextual variables.

## 2. MATERIAL AND METHODS

### 2.1. Study design

An experienced European motorcycling rider was assessed throughout a competitive week of the FIM CEV Repsol Moto2 European Championship. Heart rate average and sympathetic-parasympathetic ratio were measured during eight training and competitive sessions. These variables were analysed in three contextual scenarios comparison: session type, laps, and track segments.

### 2.2. Participants

One European-level male rider participated voluntarily in this research (age: 19.2 years; height: 172.5 cm; body mass: 69.3 kg). This rider had an experience of more than five years and did not suffer from any physical limitation or musculoskeletal injury that could affect the performance during the competition. Before the start of this investigation, the rider was fully informed about the testing and their written informed consent was obtained. The procedure was approved by the institutional Ethics Review Committee and conformed to the code of ethics of the World Medical Association (Declaration of Helsinki, 7th edition). The procedure was approved by the Bioethics Commission of the University of Murcia (Reg. Code 2061/2018).

### 2.3. Equipment

*Anthropometric characteristics.* The height and body mass of the rider were assessed. Specifically, height was measured to the nearest 0.5 cm during a maximal inhalation using a wall-mounted stadiometer (SECA, Hamburg, Germany). Body mass was obtained with an 8-electrode segmental body composition monitor BC-601 model (TANITA, Tokyo, Japan).

*Internal workload and tracking*. To register the heart rate, a WIMU PRO™ inertial device (RealTrack Systems, Almeria, Spain) was placed in the front part of the motorbike where receipt the data of the GARMIN® HR band. (Garmin Ltd., Olathe KS, USA) which sent the data thanks to Ant+ technology. The sampling frequency was 4 Hz and the process has been analysed and detailed previously (Molina-Carmona et al., 2018). Regarding the tracking of the motorbike, the device has a satellite navigation system (GNSS) with a sampling frequency of 10 Hz, being its validity and reliability analysed previously (Bastida-Castillo et al., 2018). The heart rate and tracking data are synced in time for analysis.

### 2.4. Variables

*Internal load*. The internal load is considered as the stress and physiological reaction facing a stimulus and can be measured by heart rate telemetry (HR) (McLaren et al., 2018). In the present study, two variables depending on heart telemetry were analyzed: heart rate average ($HR_{AVG}$) and sympathetic-parasympathetic ratio (RS-Ps). $HR_{AVG}$ is considered as the number of beats per minute realized by the heart during the activity, while RS-Ps is the relationship between the sympathetic and the parasympathetic activity that reflects the autonomous balance through the heart rate variability and it is calculated as the quotient between Stress Score (sympathetic activity) and the transversal axis SD1 (parasympathetic activity) (Manso, 2013). Related to the RS-Ps, four groups were created by *k*-means clustering algorithm considered all data collected in race week sessions following previous research in sport (Fernández-Leo et al., 2020; García-Rubio et al., 2015): (a) low (0-to-89), (b) moderate (89-to-165), (c) high (166-to-373), and (d) very high (over than 374).

*Contextual variables*. Different contextual variables that could influence the rider's performance have been considered for analysis: (a) session (*n*=8), considered as each period of time or laps that the rider is on the track and is divided in free practice 1 (FP1), free practice 2 (FP2), free practice 3 (FP3), free practice 4 (FP4), free practice 5 (FP5), qualifying 1 (Q1), qualifying 2 (Q2) and race; (b) lap (*n*=12 to 22), each time that the rider complete the total track distance and is variable in each session (FP1, *n*=19; FP2, *n*=22; FP3, *n*=20; FP4, *n*=16; FP5, *n*=21; Q1, *n*=12; Q2, *n*=22; Race, *n*=13); (c) segment (*n*=20), small section of the track created in relation with the technical indications of the rider's coach and the specific brake and acceleration points of the rider.

## 2.5. Procedures

The performance assessment of the rider was realized during the 7$^{th}$ race week of the FIM CEV Repsol Moto2 European Championship that had placed in the "Albacete Motorsport Circuit" (Albacete, Spain). The race week was between the 13-16$^{th}$ of October 2018. A total of eight sessions were analyzed and their distribution is shown in table 1.

**Table 1.** *Periodization of sessions during race week.*

| Session type | Day | Nº | Session | Time |
|---|---|---|---|---|
| Free Practice | Thursday (13/10/2018) | 1 | Free Practice 1 (FP1) | 9:00 (40 min) |
| | | 2 | Free Practice 2 (FP2) | 11:30 (40 min) |
| | | 3 | Free Practice 3 (FP3) | 14:00 (40 min) |
| | Friday (14/10/2018) | 4 | Free Practice 4 (FP4) | 11:15 (40 min) |
| | | 5 | Free Practice 5 (FP5) | 14:20 (40 min) |
| Qualifying | Saturday (15/10/2018) | 6 | Qualifying 1 (Q1) | 10:45 (40 min) |
| | | 7 | Qualifying 2 (Q2) | 14:10 (40 min) |
| Race | Sunday (16/10/2018) | 8 | Race 1 (R1) | 11:00 (13 laps) |

This track has a total length of 3550 m and is distributed at 14 corners (8 right corners and 6 left corners). The technical characteristics of this track can be consulted in https://www.circuitoalbacete.es/circuito/caracteristicas-tecnicas/. To the subsequent analysis, the track was divided in 20 segments in relation to the technical indications of the rider's coach and the specific brake and acceleration points of the rider as follows: (1) T-C1, start line to corner 1; (2) C1, corner 1; (3) C2, corner 2; (4) C3, corner 3; (5) C4, corner 4; (6) C5, corner 5; (7) C6, corner 6; (8) T-C7, straight to corner 7; (9) C7, corner 7; (10) T-C8, straight to corner 8; (11) C8, corner 8; (12) C9, corner 9; (13) T-C10, straight to corner 10; (14) C10, corner 10; (15) T-C11, straight to corner 11; (16) C11-12, corners 11 and 12; (17) C13, corner 13; (18) T-C14, straight to corner 14; (19) C14, corner 14; and (20) C14-M, corner 14 to finish line (see Figure 1 for more details). For this process, SPRO$^{TM}$ software (RealTrack Systems, Almeria, Spain) was used through GIS monitor.

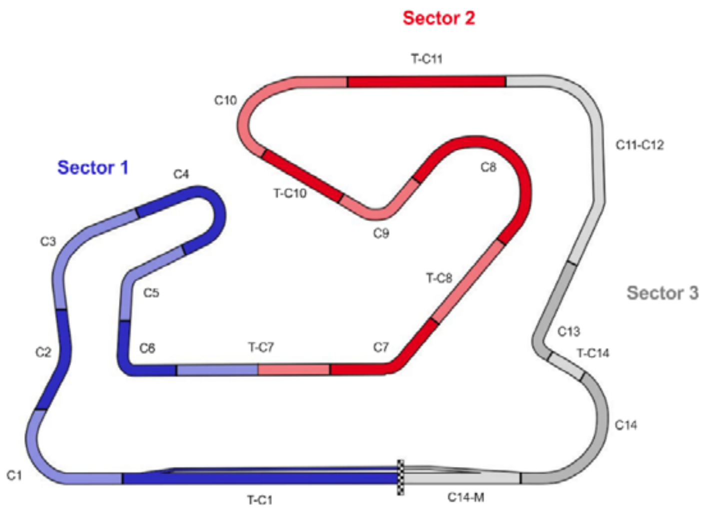


**Figure 1.** *Designed segments of the circuit in relation to the coach's indications and rider's driving. The colours of the track represent the sector: (a) blue, sector 1; (b) red, sector 2; and (c) grey, sector 3*

30-min before beginning the sessions, the heart rate band and the inertial devices were attached correctly. The heart rate band was placed in the chest of the rider, at the height of the xiphoid process. On the other hand, the inertial device was placed in the cockpit of the motorbike, under the fairing and on the back of the dashboard. The inertial device location was chosen due to allow the best transmission of the heart rate (in front of the chest) and GPS signal (the fairing made by fibreglass with a thickness less than 1 cm protected the device and allow perfectly the GPS tracking).

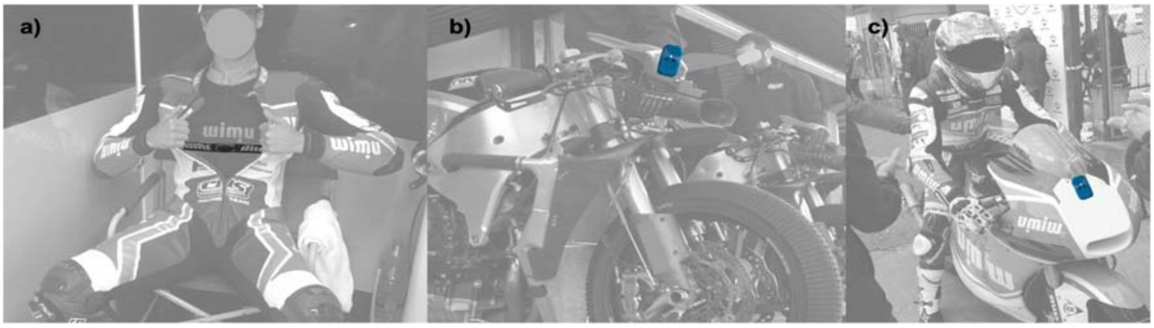


**Figure 2.** *Location of (a) heart rate band in the rider and (b-c) inertial device in the motorbike's cockpit.*

Once the devices are placed, previous to the session start, the data was monitored in real-time with SVIVO™ software to verify the perfect functioning of the devices. When the rider finished each session, they had a rest period of 15-min before remove the heart rate band and the inertial device from the motorcycle. All variable data were collected throughout the tests at a specific sampling frequency of the sensors. Then, the data was downloaded, averaged over each segment for subsequent analysis and downloaded in an Excel spreadsheet by SPRO™ software.

2.6. Statistical analysis

A descriptive analysis (mean and standard deviation; M±SD) was performed to characterize the sample. The data distribution and the homogeneity of variance were calculated through Kolmogorov-Smirnov and Levene tests obtaining a parametric distribution (Field, 2013). Therefore, a MANOVA test was performed between independent variables (sessions, laps, and segments) and dependent variables (RS-Ps and $HR_{AVG}$). Pairwise comparisons were realized by Bonferroni post-hoc. The effect sizes were obtained by omega partial squared ($\omega_p^2$) was interpreted as: >0.01 *low*; >0.06 *moderate* and >0.14 *high* (Cohen, 1988).

Finally, a correlational analysis to identify the existence of relations between independent variables (sessions, laps and segments) and dependent variables (RS-Ps and $HR_{AVG}$) was realized by *Pearson correlation coefficient* interpreted as: *insignificant* ($r < .10$), *low* ($.10 < r < .30$), *moderate* ($.30 < r < .50$), *high* ($.50 < r < .70$), *very high* ($.70 < r < .90$), *almost perfect* ($r > .90$) and *perfect* ($r = 1.00$) (Field, 2013). El nivel de significancia se estableció en $p < 0{,}05$. The significance level was established in $p<.05$. Data analysis was performed by *Statistical Package for the Social Science* (SPSS Statistics, version 24, IBM Corporation, Armonk, NY, USA) and plots were designed by GraphPad Prism (version 7, GraphPad Software, San Diego, CA, USA).

## 3. RESULTS

Firstly, an effect of the segments in RS-Ps ($F$=3.86; $p$<.01; $\omega_p^2$=0.03 *low*) was found. Also, the results showed a significant effect of the sessions ($F$=792.86; $p$<0.01; $\omega_p^2$=0.72 *high*), laps ($F$=2083.18; $p$<0.01; $\omega_p^2$=0.95 *high*) and the interaction between sessions and laps in $HR_{AVG}$ ($F$=41.99; $p$<0.01; $\omega_p^2$=0.62 *high*). Instead, no effects were found in RS-Ps by the sessions. There was no effect of the segments on $HR_{AVG}$. In addition, no significant effects of the interaction between sessions and segments or the interaction between laps and segments on none of the internal load variables ($F$<1.50; $p$>0.09; $\omega_p^2$=0.00).

Concerning the effect of segments on RS-Ps, statistical differences were found in whole sessions between T-C10, T-C14 and the rest of segments (T-C10 > T-C14 > rest of segments). In the analysis by sessions, statistical differences by segments were found in FP2 ($F$=2.78; $p$<0.01; $\omega_p^2$=0.07 *moderate*; T-C10 = T-C14 = C2 > rest of segments), FP3 ($F$=2.94; $p$<0.01; $\omega_p^2$=0.08 *moderate*; T-C10 = T-C14 > rest of segments), Q2 ($F$=4.38; $p$<0.01; $\omega_p^2$=0.13 *moderate*; T-C10 = C-14 > T-C11 > rest of segments) and race ($F$=2.78; $p$<0.01; $\omega_p^2$=0.05 *low*; T-C10 = T-C14 > rest of segments) (see Figure 3 for more details).

Figure 4 shows the effect of sessions and laps on $HR_{AVG}$. In pairwise comparisons, differences were found between sessions ($p$<0.01; Q2 > Q1 = FP5 = FP4 = FP3 = Race > FP2 > FP1). Finally, the correlation analysis between internal load and contextual variables was shown in Table 2. A tendency of $HR_{AVG}$ increasing with moderate correlation was found over sessions throughout the race week ($r$=.315; $p$<0.01) and the number of laps in the track ($r$=.280; $p$<0.01), and low correlation with the track segments ($r$=.101; $p$<0.05). Instead, no significant correlations were found on RS-Ps with sessions, segments, or laps.

**Table 2.** *Correlational analysis between internal load and contextual variables analysed in the present study.*

| | RS-Ps | $HR_{AVG}$ |
|---|---|---|
| Sessions | -.029 | .415** |
| Laps | .033 | .380** |
| Segments | .043 | .101* |

**Note.** *RS-Ps: Sympathetic-Parasympathetic ratio; $HR_{AVG}$: Average heart rate. *Significative correlation at p<0.05 level; ** Significative correlation at p<0.01 level.*

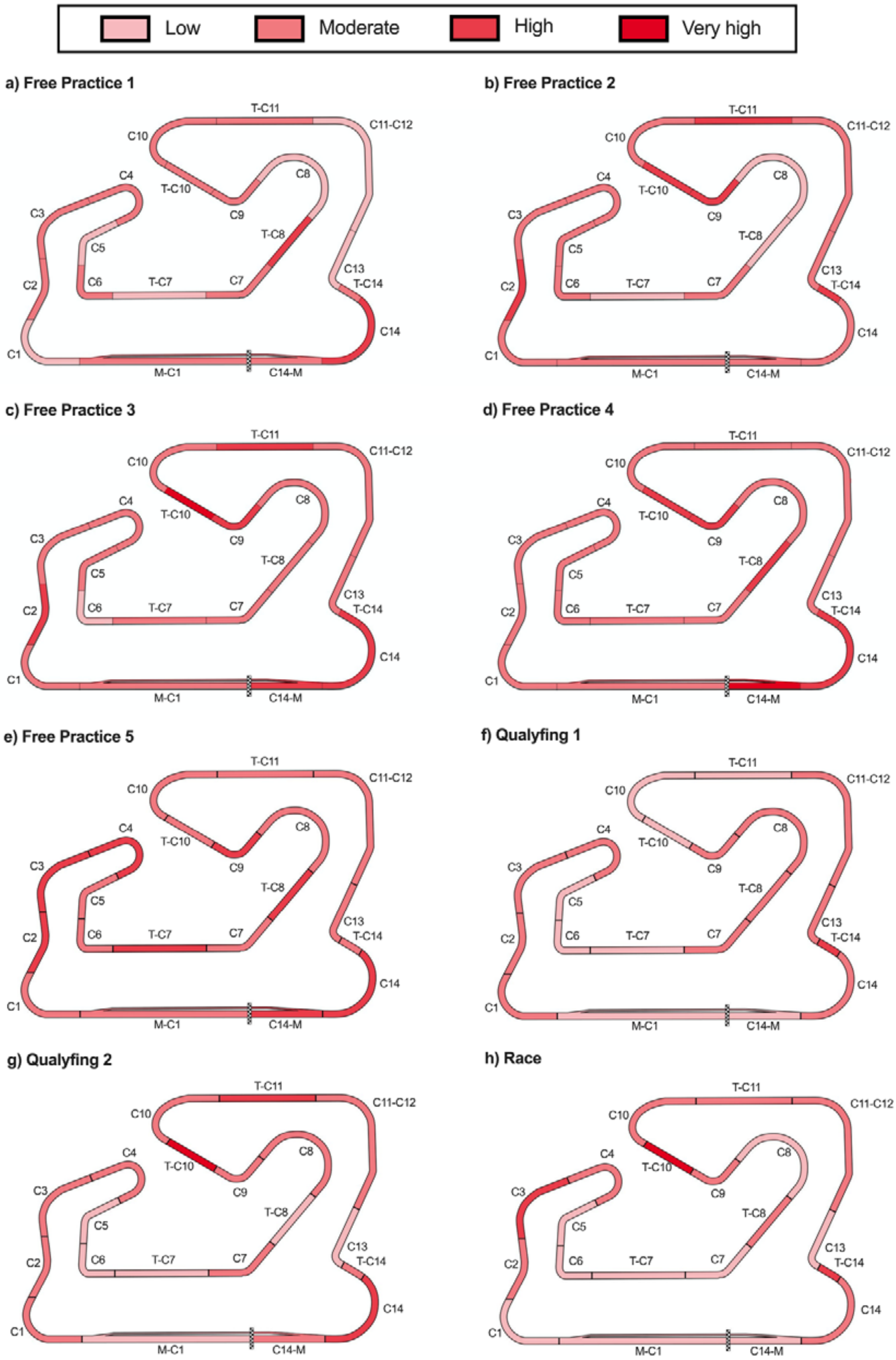


**Figure 3.** *RS-Ps sectors' behaviour in each session of the rider during the 7th race week of the FIM CEV Repsol Moto2 European Championship.*

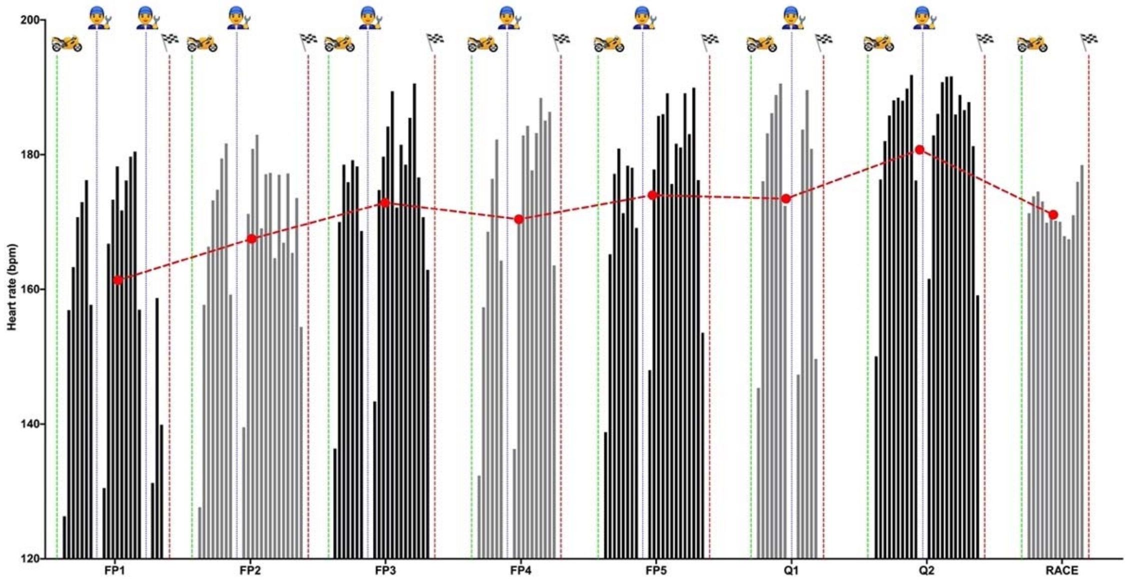


**Figure 4.** *Dynamics of HRAVG between laps and sessions.*
*start of the session, technical stop, end of the session.*

## 4. DISCUSSION

The purpose of this study was to investigate the chronotropic response through heart rate during a competitive week in speed motorcycling and its variation according to contextual variables. The main findings of this study were that $HR_{AVG}$ was significantly influenced by laps and sessions while RS-Ps was influenced by specific segments of the track. In addition, a moderate and positive correlation on $HR_{AVG}$ was observed over the sessions of the competitive week.

To the best of the authors' knowledge, this is the first study to analyze RS-Ps in motorcycling. Differences in RS-Ps between segments of the track were greater than the rest of segments, specifically in T-C10 and T-C14. These parts of the track, which one of them belongs to the straight run before the last curve before crossing the finish line, elicited the greatest RS-Ps. These results suggest that the rider is exposed to higher levels of sympathetic stress and the physiological demands of these segments need to be trained (Naranjo-Orellana et al., 2015). Although there were moderate differences between segments in FP2 ($F$=2.78; $p<0.01$; $\omega_p^2$=0.07; T-C10 = T-C14 = C2 > rest of segments), FP3 ($F$=2.94; $p<0.01$; $\omega_p^2$=0.08; T-C10 = T-C14 > rest of segments), and Q2 ($F$=4.38; $p<0.01$; $\omega_p^2$=0.13; T-C10 = C-14 > T-C11 > rest of segments), it is to highlight that low differences ($F$=2.78; $p<0.01$; $\omega_p^2$=0.05; T-C10 = T-C14 > rest of segments) were found in the race session. This change in the rider's RS-Ps response could be due to an adaptation phenomenon after training and qualifying sessions (Vanrenterghem et al., 2017).

However, no significant effect was found of laps or sessions on RS-Ps. Given that the RS-Ps may be an early alert of fatigue (Naranjo-Orellana et al., 2015) these results lead to the conclusion that despite RS-Ps being a significant rider's stress indicator at specific segments of the track, it did not seem to be an indicator of acute fatigue.

When it comes to $HR_{AVG}$, a high effect of two contextual variables (sessions and laps) was observed. For example, there were significant differences in $HR_{AVG}$ between sessions ($p<0.01$; Q2 > Q1 = FP5 = FP4 = FP3 = Race > FP2 > FP1). From these results, two main conclusions are reached. Firstly, qualifying sessions required higher $HR_{AVG}$ than race session, which could be related to the increased aggressive riding style during the qualifying sessions in order to achieve a better start position (Tomida, 2005). However, there are several investigations on heart rate responses in motorcycling which disagree with this conclusion since they found that $HR_{AVG}$ in the race (175-195 bpm) was greater than qualifying sessions (160-190 bpm) (Brearley et al., 2014; D'Artibale et al., 2007; D'Artibale et al., 2008; Filaire et al., 2007).

Secondly, the lowest $HR_{AVG}$ was observed in free practice. Free practices give the riders the chance to get used to the track, adapt the motorbike, plan race strategies and these sessions are not timed for qualification or race purposes (D'Artibale et al., 2007). Therefore, such a low $HR_{AVG}$ not only in our study but also in previous investigations in free practices (Brearley et al., 2014, 2014; D'Artibale et al., 2007; D'Artibale et al., 2008) could be explained by two reasons showed previously, qualifying or race.

In addition, there were significant differences in $HR_{AVG}$ between laps ($F$=2083.18; $p<0.01$; $\omega_p^2$=0.95). A previous investigation on $HR_{AVG}$ found differences between three stages of the race and concluded that demands increased from the beginning to the end of the race (D'Artibale et al., 2008). Also, laps had a high interaction with sessions ($F$=41.99; $p<0.01$; $\omega_p^2$=0.62). This implies that fatigue status could be explained by changes in $HR_{AVG}$ since differences were found between laps and sessions but not between segments. Perhaps the prevalence of rider's isometric position on the motorbike increases heart rate demands (Konttinen et al., 2007) and consecutive training days do not allow an optimal recovery process. However, it is important to mention that physiological response may be dependent on the track itself and should be considered as an additional contextual variable in future studies.

Regarding the limitations of the study, it is to mention that these results have been obtained in a case study (one moto rider), although he was elite level and competed in the second maximum division of the international motorcycling. Also, data was collected during a one-week competitive period, being obtained results specific to this competitive level and track. The greatest strength of the present study is to make the first approach from scientific knowledge to the analysis of the chronotropic and autonomous cardiac response in motorcycling, since the research to date is limited, which makes it difficult to further discuss the results of this study. In addition, in the context of sports training, it must be considered that there may be methodological limitations in the calculation of variables related to heart rate variability (Calderón et al., 2020). Therefore, future studies considering the mentioned limitations are needed in order to have a better understanding of the chronotropic and cardiac autonomic responses of motorcyclists in competitive periods.

## 5. CONCLUSIONS

Contextual variables of motorcycling such as segment, lap and session have a significant effect on motorcyclist's internal load parameters. Specifically, large differences are observed in $HR_{AVG}$ based on laps and session while RS-Ps is affected by specific track segments. However, no significant effects of laps or sessions were found on RS-Ps.

In this sense, the present research indicates that the $HR_{AVG}$ can be a useful indicator for the detection of within and between-session fatigue throughout a competitive period in motorcycling, which can be considered for the planning of sessions and the number of laps by session in order to optimize the rider's performance throughout the competition week. On the other hand, the RS-Ps was found as an indicator of rider stress in specific segments of the track, so its information may be relevant for the identification of critical points on the track and adopting strategies to reduce it, combining this information with telemetric information on the motorcycle as well as technical instructions made by the trainer regarding the rider's style of driving. Therefore, the application of both variables (RS-Ps and $HR_{AVG}$) in the monitoring of the motorcycling rider in competition can be useful for improving the physical and technical performance of the rider, as well as safety and competitive performance.

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