Time-loss injuries in MotoGP championships

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Summary

Introduction: MotoGP (Moto Grand Prix) is the premier class of motorcycle road racing events held on road circuits over a distance between 100 and 130 kilometers. Despite its worldwide popularity, there are only few studies published in the scientific literature, thus the aim of this paper is to contribute to the discussion about epidemiological data regarding the injuries of MotoGP riders.
Material and method: Riders involved in the Moto Grand Prix (MotoGP) World Championships 2019, 2020, and 2021 were studied for time-loss injuries (TLI) by searching the official websites of riders themselves, races, sports newspapers.
Results: Twenty-nine riders (age 28.0±4.7 yrs; BMI 21.8±1.2 kg/m^2) with 11.8±8.2 yrs of experience in MotoGP and in motor racing championships, participated in the MotoGP World Championships 2019, 2020 and 2021. They reported 26 TLI during races, without difference between race and pre-race practice. TLI prevalence tends to increase linearly as riders participate in more than one subsequent Championship (R^2= 0.998; p<0.001), with a risk of 100% through the entire career. Incidence of TLI was 21.2/1000 hours of race (CI 95%: 9.7-32.8). TLI were classified as contusions (35%), bone fractures (32%), sprains (10%), concussions (10%), compartment syndromes (6%) and reopening of surgical wound (3%). Fractures accounted for 1.5% of the falls in the 2019-2021 championships and for 59% of TLI in career, affecting the upper limb in 62% of cases of fractures. Injuries were due to lowside (46%), collisions (38%), highside (8%), speed wobble (4%) and gust of wind (4%). The median absence from trainings and competitions due to TLI was 18 days (range 1-271).
Conclusions: Training sessions and testing are equally occasions for TLI and should be considered for prevention and safety promotion of MotoGP riders.

Key words:
Epidemiology. Fractures. Return to competition.

Lesiónes con pérdida de tiempo de participación en campeonatos de MotoGP

Resumen

Introducción: MotoGP (Moto Grand Prix) es la clase principal de eventos de carreras de motos en carretera que se llevan a cabo en circuitos de carretera en una distancia de entre 100 y 130 kilómetros. A pesar de su popularidad mundial, existen pocos estudios publicados en la literatura científica, por lo que el objetivo de este artículo es contribuir a la discusión sobre la epidemiológia de los pilotos de MotoGP.
Material y método: Se estudiaron los pilotos que participaron en los Campeonatos del Mundo de MotoGP 2019, 2020 y 2021 para detectar lesiones por pérdida de tiempo (TLI) mediante una búsqueda en los sitios web oficiales de los propios pilotos, carreras y periódicos deportivos.
Resultados: Veintinueve pilotos (edad 28,0±4,7 años; IMC 21,8±1,2 kg/m^2) con 11,8±8,2 años de experiencia en MotoGP y en campeonatos de motociclismo, reportaron 26 TLI durante las carreras, sin diferencia entre carreras y práctica previa a las carreras. La prevalencia de TLI tiende a aumentar linealmente a medida que los pilotos participan en más de un Campeonato (R^2= 0,998; P <0,001), con un riesgo del 100% a lo largo de toda la carrera deportiva. La incidencia de TLI fue de 21,2/1000 horas de carrera (IC 95%: 9,7-32,8). Los TLI se clasificaron en contusiones (35%), fracturas (32%), esguinces (10%), conmociones cerebrales (10%), síndromes compartimentales (6%) y reapertura de herida quirúrgica (3%). Las fracturas representaron el 1,5% de las caídas en los campeonatos 2019-2021 y el 59% de TLI en carrera, afectando al miembro superior en el 62% de los casos de fracturas. Las lesiones se debieron a lowside (46%), colisiones (3 %), highside (8%), oscilaciones de velocidad (4%) y ráfagas de viento (4%). La ausencia media de entrenamientos y competiciones debido a TLI fue de 18 días (rango 1-271).
Conclusiones: Las sesiones de entrenamiento y las pruebas son igualmente ocasiones para TLI y deben ser consideradas para la prevención y promoción de la seguridad de los pilotos de MotoGP.

Palabras clave:
Epidemiología. Fracturas. Vuelta a la competición.

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Introduction

MotoGP (Moto Grand Prix) is the premier class of motorcycle road racing events held on road circuits sanctioned by the Fédération Internationale de Motocyclisme (FIM)[1].

The MotoGP World Championship is composed of 20 Grands Prix. Each round lasts between 40 and 45 minutes and is run over a distance between 100 and 130 kilometers, depending on the circuit. A sliding scale of points are awarded at the finish for the first 15, and the final ranking is calculated from the sum of the awarded points.

MotoGP riders have three, 45-minute sessions of practice at the end of which a first ranking is established. After a fourth 30-minute session, whose times do not count, the riders whose times are slower than the first ten take part in a fifteen-minute qualifying session. The fastest two riders from this session are allowed to join the session bringing together the fastest ten riders for another qualifying session used to determine the first twelve places on the grid. Each line is composed of three riders. To qualify each rider must post a time at least equal to 107% of the time achieved by the fastest rider.

The World Championship is raced using 1000 CC prototypes, yielding a power around 300 HP (220 kW), able to accelerate from 0 to 100 km/h in just over two seconds, reaching top speeds of up to 360 km/h, although organizers have agreed on a set of regulations to reduce speed and improve safety[1-2].

Riders have an allocation of seven engines for the whole season. Since 2017, all the teams use the same electronic management system, provided by the championship promoter. Each rider is equipped with a limited number of tires. Bikes must have a minimum weight of 157 kg, including no more than 22 liters of fuel, normal levels of oil and water, and all additional equipment attached to the motorcycle[1].

The characteristics of motorcycle races mean that intense neuromuscular activity is required to ride fast and maneuver the motorcycle on the track while counteracting the numerous inertial stresses to which the rider is subjected[3-6]. The mean speeds of the races are usually higher than 160 km/h[7], and the rider must brake more than 170 times generating a mean inertial stress higher than 1g, leaning into the curves more than 370 times per race[3]. As a consequence, the main physiological demands during official competitions can be summarized in: i) heart rates (HR) almost always above 90% HRmax[3,7,8], with a positive correlation between the frequency of occurrence of HRmax and mean speed of racing, but not between cardiac load and perceived track difficulty[9]; ii) blood lactate concentrations measured after racing indicate the involvement of the anaerobic metabolism, with values increased more than two-fold as compared to resting values (of 2.0±0.1 mmol/L)[6] attaining values around or slightly above the anaerobic threshold of 4 mmol/L[3-5]; iii) muscle involvement lead to hypertrophic forearms[10] with left dominance demonstrated in off-road riders[11]; iv) the relationships between anthropometric characteristics and the power of the engines indicate that small and light riders might be advantaged even if this hypothesis needs further investigations[3]; v) both the qualifying session and the race induce a rise in the cortisol levels[6], indicating a high level of stress[12] characterized by an anticipatory response to the contest[6].

Due to the high speeds attained and the battles between riders, falls and collisions are not uncommon among elite motorcycle riders[13], but the relative incidences of injuries requiring surgery or fatal are low[14].

Despite its worldwide popularity, the continuous motorbike's technological improvement[15] and the considerable business interest, there are only few research published in the scientific literature regarding the injuries and the epidemiology of motorcycle racing[14,16-22], thus the aim of this paper is to contribute to the discussion about epidemiological data regarding the injuries of MotoGP riders.

Material and method

Three seasons of the MotoGP World Championships were studied (2019, 2020, 2021), analyzing the official reports of every race (Table 1), and searching the official websites of the races, the personal websites of the riders and electronic sports newspapers for time-loss injuries.

Searches were carried out using Google and Yahoo as web search engines, typing several keywords: MotoGP, fall, injury, training, race, and the names of the races and of the riders variously associated with each other. When an injury was found, the information was checked, and the web search was deepened for the place, date, and name of the race.

For all the riders who participated in these three Word Championships, the search was performed also for time loss injuries occurred during their entire career, including moto racing championships (Moto2, Moto3, MotoGP) and training sessions out of the circuits. Consultation of websites was done from September the 1st to December the 20th 2021, thus this is a retrospective study.

The analysis were performed on publicly available data, in accordance with the 1964 Helsinki declaration involving human participants and its later amendments or comparable ethical standards.

A time-loss injury (TLI) was defined as an injury that leads a rider to be unable to take full part in future races or training sessions.

Race exposition was calculated from the time taken by every rider to complete the races added to the race times of the riders who did not finish the competition.

Data were anonymized and analyzed by descriptive statistics. Incidence was calculated dividing the number of injuries by exposition and was expressed per 1000 hours and per 1000 km of race, with 95% confidence interval[23]. The χ^2 test was used to compare injury rate between practice and race, considering $p < 0.05$ as significant. Relationship between prevalence and number of participations in World Championships was analyzed by simple linear regression.

Results

Twenty-nine riders with 28.0±4.7 yrs of age (range 21.0-41.9); 66.9±3.8 kg (62.0-80.0); 1.75±0.05 m (1.65-1.84); 21.8±1.2 kg/m^2 (19.8-25.0) and 6.0±4.5 yrs (1.0-20.0) of experience in MotoGP and 11.8±8.2 yrs of experience in motor racing championships, were considered for the study. Nineteen riders (66%) participated in all the three seasons, three (10%) in two seasons and seven (24%) in one season. Prevalence and incidence data are shown in Table 2 and Table 3 respectively.

Table 1. List in alphabetical order of the circuits of the three seasons analyzed and their characteristics.

Circuit (country)	Curves N°	Length km	Laps N°	Race km	Winner time mm:ss	Average speed km/h
Alcaniz (ESP)	17	5.077	23	116.771	41:44.422	167.8
Assen (NED)	18	4.542	26	118.092	40:35.031	174.5
Austin (USA)	20	5.513	20	110.260	41:41.435	158.6
Barcelona (ESP)	14	4.657	24	111.768	40:21.749	166.1
Brno (CZE)	14	5.403	21	113.463	41:38.764	163.4
Buriram (THA)	12	4.554	26	118.404	39:36.223	179.3
Jerez (ESP)	13	4.423	25	110.575	41:05.602	161.4
Le Mans (FRA)	14	4.185	27	112.995	47:25.473	142.9
Losail (QUA)	16	5.380	22	118.360	42:28.663	167.1
Misano (ITA)	16	4.226	27	114.102	41:48.305	163.7
Motegi (JAP)	14	4.801	24	115.224	42:41.492	161.9
Mugello (ITA)	15	5.245	23	120.635	41:16.344	175.3
Phillip Island (AUS)	12	4.448	27	120.096	40:43.729	176.9
Portimao (POR)	15	4.592	25	114.800	41:48.163	164.7
Sachsenring (GER)	13	3.671	30	110.130	41:07.243	160.6
Sepang (MAS)	15	5.543	20	110.860	40:14.632	165.2
Silverstone (GBR)	18	5.900	20	118.000	40:20.579	175.4
Spielberg (AUT)	10	4.318	27	116.586	38:07.879	183.4
Termas de Rio Hondo (ARG)	14	4.806	25	120.150	41:43.688	172.7
Valencia (ESP)	14	4.005	27	108.135	41:15.481	157.2

Table 2. Prevalence of time-loss injuries in the three MotoGP Championships. Prevalence tends to increase linearly as riders participate in more than one Championship (R^2= 0.998; p<0.001).

Championship	Injured riders (N)	Injures (N)	Riders (N)	Prevalence (±95%CI)
2019	8	11	23	35% (15%-54%)
2020	6	7	22	27% (9%-46%)
2021	5	8	25	20% (4%-36%)
Participation in 3 Championships	15	26	29	52% (34%-70%)
Participation in 2 Championships	10	17	26	38% (20%-57%)
Participation in 1 Championship	6	9	23	26% (8%-44%)

Table 3. Annual and cumulative incidence of time-loss injuries during races. Championships data regarding drivers, finishers and DNF were expressed as mean ± SD of participants per race.

Championship	Races (n)	Drivers (n)	Finishers (n)	DNF (n)	Injuries (n)	Exposition (h)	Incidence/1000h (±95%CI)	Exposition (km)	Incidence/1000km (±95%CI)
2019	19	21.5±1.1	17.6±2.0	3.8±2.0	5	232	21.6 (2.7%-40.4%)	42,980	0.1 (0.0%-0.2%)
2020	14	20.4±1.1	16.8±2.6	3.6±2.1	4	155	25.8 (0.5%-51.1%)	27,935	0.1 (0.0%-0.3%)
2021	18	21.4±1.0	18.0±1.8	3.4±1.9	4	225	17.8 (0.4%-35.2%)	41,274	0.1 (0.0%-0.2%)
Totals	**51**	**1,080**	**894**	**186**	**13**	**612**	**21.2 (9.7-32.8%)**	**112,198**	**0.1 (0.1%-0.2%)**

DNF: did not finish.
Note that the number of races in each of the three championships was less than usual due to the COVID-19 pandemic.

Over the three seasons, there were 678 falls during the races (Table 4), 26 (4%) resulting in TLI involving one or more than one rider.

Mechanism of the 26 injuries were due to low-side, i.e., falling toward the inside of the turn (N=12; 46%), collisions (N=10; 38%), high-side i.e., falling over and toward the outside of the turn (N=2; 8%), speed wobble (N=1; 4%) and gust of wind (N=1; 4%).

In the three considered seasons riders reported three more acute TLI during running (knee sprain), mountain biking (wrist fracture) and

Table 4. Falls during the three seasons, divided by phases of the races of MotoGp World Campionship.

	2019	2020	2021	Average±SD
Races (n)	19	14	18	17.0±2.6
Falls during free practice 1	23	15	27	21.7±6.1
Falls during free practice 2	37	30	36	34.3±3.8
Falls during free practice 3	20	29	39	29.3±9.5
Falls during free practice 4	21	18	34	24.3±8.5
Falls during qualifying practice 1 (Q1)	14	11	23	16.0±6.2
Falls during qualifying practice 2 (Q2)	19	12	27	19.3±7.5
Falls during Warm-up	12	9	19	13.3±5.1
Falls in race	74	56	73	67.7±10.1
Total of falls	**220**	**180**	**278**	**226.0±49.3**

Source of data: http://www.motogp.com.

Table 5. Falls and time-loss injuries (TLI) occurred in race and practice before the race (free practices, qualifying and warm up).

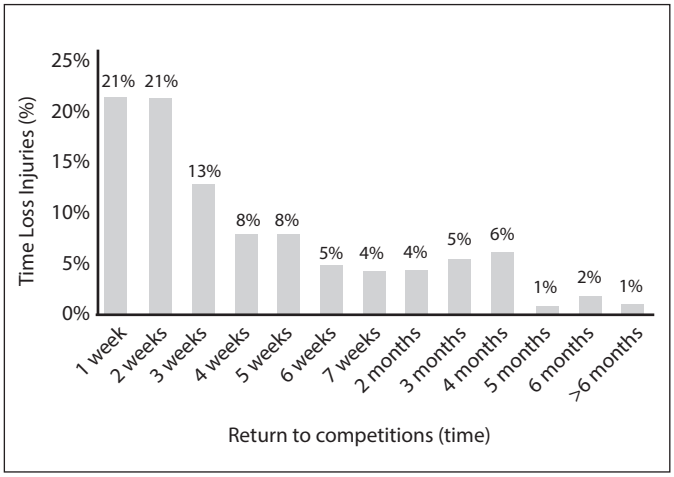
Year	Races	Race			Practice			Race+practice		
		Falls	TLI	%	Falls	TLI	%	Falls	TLI	%
2009	19	74	5	7%	146	6	4%	220	11	5%
2020	14	56	4	7%	124	3	2%	180	7	4%
2021	18	73	4	5%	205	4	2%	278	8	3%
Totals	**51**	**203**	**13**	**6%**	**475**	**13**	**3%**	**678**	**26**	**4%**

motocross training sessions (concussion), and two chronic TLI injuries due to forearm compartment syndrome (both bilateral). Thus, in the considered period we found a total of 31 TLI (84% during MotoGP races and practice and 16% during training); 3 of them were considered as polytraumas (10%). These TLI were classified as contusions (N=11; 35%), bone fractures (N=10; 32%), sprains (N=3; 10%), concussions (N=3; 10%), compartment syndromes (N=3; 6%) and reopening of surgical wound (N=1; 3%) (Table 5).

Considering their entire career until the time of the present study, riders reported 5.8±4.2 (range: 1-13) TLI each, and the median absence from trainings and competitions due to a TLI was 18 days, ranging from 1 to 271 (Figure 1). Fractures were the TLI more frequent, accounting for 59% of TLI, mainly affecting the upper limbs (62% of the fractures).

During their career, riders were affected by TLI during the free and preseason testing sessions (12%), motocross training sessions (8%), mountain biking (2%) and running (1%).

Figure 1. Time for return to competitions after the 165-time loss injuries reported by 29 MotoGP riders during their career.



Discussion

In this paper we analyzed TLI only occurred during three subsequent MotoGP World Championships, excluding the less powerful Moto2 and Moto3 classes, which participate in the same race weekends with different time schedules. The main finding of the study was that there was the same number of TLI in races compared to practices, qualifying heats and warm-ups (i.e., 50%; $p > 0.05$), representing the 6% and 3% of the falls respectively. Campillo-Recio *et al.*[14] have considered together the three classes of the World Championship in the 2013-2017 seasons and have reported that the 57% of the accidents took place during races. On the other hand, an injury rate of 19% was reported during races for MotoGP only in the 2014 World Championship[21] and of 26% for Japanese road motorcycle riders during competitions[18]. In the latter study Authors considered only major injuries, i.e., injuries that interrupted participation for a period of more than one month[18].

The incidence of TLI has only been calculated for races because no precise data on exposure during tests and qualifying heats have been recorded in this study. The incidence of TLI in the three analyzed seasons was 21.2/1000 hours of race (Table 3). However, it is difficult to compare our incidence data with other, such as those published by Tomida *et al.*[18] who reported an injury incidence of 25.6/1000 hours for first class Japanese motorcycle riders referring injuries defined as "an inability to train or compete in national championships", or by Bedolla *et al.*[16] who reported a "crash" incidence of 96.7/1000 hours considering three US MotoGP races during the 2013 season of the American Red Bull MotoGP series.

In motor sports the incidence can be expressed also per 1000 km, as reported by Zasa *et al.*[21] who defined injury as "inability to train or compete" finding an incidence of 4.1 and 3.8/1000 km of practice and race respectively during the 2014 MotoGP World Championship, while in our three years study we calculated an incidence of TLI of 0.1/1000 km of race.

All these differences may depend on the definition of accident, injury, or time loss injury, and on the different circuits and sample of pilots analyzed. They may also depend on the different year in which the races took place between 2002 and 2021, even considering that the speed of dry racing has increased over a period of 20-years[18], but also because of the improvement in safety and prevention multimodal measures and changes of some rules of the competitions. Anyway, these data could help to understand the epidemiology of MotoGP injuries, although a better agreement and uniformity in the collection of epidemiological data would be desirable[16].

In MotoGP falls and accidents are common (Table 4), but serious injuries to brain, spinal cord, chest, and abdomen or fatal injuries are rare[14,21]. The average risk of injury can be estimated from the prevalence, i.e., the number of injured riders divided by the number of riders at risk (Table 2), that tends to increase linearly as riders participate in more than one MotoGP championship ($R^2 = 0.998$; $p < 0.001$). Analyzing the 29 riders involved in the present study, it emerged that everyone sustained almost one TLI during their career (not only in MotoGP) indicating a 100% risk of TLI in the career.

It is well known that the mean age of MotoGP riders is higher than those of Moto2 and Moto3. Campillo-Recio *et al.*[14] reported a mean age of 26.9±0.2 (n=23), 23.7±0.4 (n=32) and 18.7±1.0 (n=33) yrs for MotoGP, Moto2 and Moto3 respectively, similar of those reported for the 2014 World Championships[21]. In the present study the mean age was 28.0±4.7 yrs, confirming that riders in MotoGP tend to have more experience than those competing in the other classes, but it seems that this fact does not prevent from further injuries due to the high speed reached by the motorbikes and the fights to overtake. Anyway, it was reported that Moto2 and Moto3 riders showed respectively 1.8 and 2.6 times higher relative risk for injuries compared to MotoGP riders[21].

It is interesting to note that some of the recorded TLI occurred during training out of the circuits. They accounted for 16% during the period considered and these events should be taken into account for accident prevention. In particular, the riders train with running and mountain biking, but frequently riding motocross or dirt bikes, so we recorded 8% of the TLI in the careers of our sample during motocross training sessions, a finding that should be considered for prevention.

Most of the TLI were fractures, because of high-speed crashes. They accounted for 1.5% of the falls in the 2019-2021 seasons, in accordance with Campillo-Recio *et al.*[14] who reported 119 fractures out of 9092 accidents (1.3%) in the 2013-2017 period, 70% of them requiring surgery. In the study carried out by Zasa *et al.*,[21] on the database of the Clinica Mobile regarding the 2014 season of MotoGP, the fractures were 18 out of 36 injuries (50%). In our sample, fractures accounted for 59% of TLI in career, affecting the upper limb in 62% of cases of fractures, as result of falling sideways mainly onto the shoulder[14].

Our study confirms that the most frequent mechanism of injury was low-side, even if the percentage of 46% of TLI resulted lower than that of 70% reported by Bedolla *et al.*[16]. Most of the fractures involved the upper body, often requiring surgery. Campillo-Recio *et al.*[14] reported that, after fracture, the average time until the return to competition in elite riders was two circuits, so that they all were back riding competitively within one to five weeks. In case of minor injuries, the return to competitions can be very fast, thanks to modern mini-invasive techniques of care, and in some cases of mini-surgery or conservative treatment return to competition can be immediate, depending on the site and the type of injury.

Considering the entire career of the riders, the median time for return to competitions after a TLI was 18 days and most of the injuries recovered within less than one month (Figure 1). However, injuries due to polytrauma needed longer times for return to competitions, up to more than six months.

Finally, our study recorded also two TLI injuries due to chronic exertional compartment syndrome affecting both forearms, which etiology is somewhat unclear. Factors involved are the effort to stabilize the engine and the repetitive flexion-extension maneuvers required for handling the throttle, when unilateral. Prevalence of 16% was observed in international level racers[4]. These are overload injuries mainly affecting motocross riders[24], in 95% of cases bilaterally[25]. However, 34% of the MotoGP riders studied in this paper were affected by this overload pathology during their career. In 71% of the cases the localization was in their right forearm. All were treated by surgery with a median time to return to competitions of 14 days (range 9-50). Open or minimally invasive fasciotomy, or endoscopy-assisted compartment release can be considered when conservative therapy fails[26]. Prevention with proper conditioning and technique of the upper arms are the keys, also considering that riders utilize motocross sessions for training.

Limits

This is an observational retrospective study, in which the use of web and media sources of information posed a challenge to data collection and understanding of the circumstances of the injuries. These reports allow for the collection of limited data regarding the injury, so it is challenging to obtain detailed information about the casualty and precisely analyze it. Only TLI were considered, however some riders can participate in trainings and races although affected by minor injuries, according with FIM regulations concerning the medical assessment conducted to permit return to competition.

Conclusions

Despite the risk that riders constantly run during MotoGP championships, fatal events and those with serious consequences are not frequent at all. Injuries are the result of high-speed falls involving mainly the upper limbs. They may cause fractures that require surgery, leading to average absences from competitions of less than one month. Training sessions and testing are equally occasions for time loss injuries and should be considered for prevention and safety promotion of MotoGP riders.

The prevention of injuries should be mainly based on the multimodal safety measures adopted by the organizers, the riders, and the manufacturers, with particular emphasis on the physical fitness of the rider, which is also necessary to avoid functional overload and the resulting pathologies such as the compartment syndrome of the forearms.

Further longitudinal studies are necessary to better understand all the risk factors and how to prevent injuries in MotoGP.

Conflict of interest

The authors do not declare a conflict of interest.

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