High-side falls: Analysis of videos and airbag data collected during racing accidents.

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Abstract:

Smart wearable airbags are mandatory in MotoGP World Championship since 2018. They led to a significant reduction of clavicle fractures and provided accurate accidentological data based on recorded linear accelerations and angular velocities. High-side falls, where the rider is ejected upwards by the motorcycle, remain a severe accident scenario for track and road riders but rarely addressed. Comparing video, airbag data and medical reports this work aims to investigate the dynamics of motorcycle riders during high-side accidents in order to improve the design of protective equipment. Five high-side falls of MotoGP riders wearing In&motion airbag technology were studied. Videos were used to understand the sequence of events and define the duration of the accidents as well as impact locations on the human body. Data collected by the airbag was analysed to validate video-based accident chronology, identify the instant of airbag triggering and quantify the severity of the impacts. Information about injuries sustained by the riders were obtained from medical reports. The riders impacted the ground between 721 and 1030 milliseconds after the ejection from the motorcycle leading to resultant accelerations from 19 to 28 G. The airbag triggered between 35 and 299 milliseconds after the ejection of the riders and protected them against the first impact with the ground in all the studied falls. The back, the shoulder and the pelvis were the first impacted parts of the torso. Four riders were transferred to the medical centre of the circuit and only one of them sustained injuries (hand and foot fractures). This work provides a first understanding of high-side accidents in terms of chronology, impact location and impact severity. The proposed methodology coupling videos and airbag data could be used to improve the effectiveness of wearable airbags in terms of accident detection, airbag inflation, covering areas and impact attenuation.

1. Introduction:

Over the last decade, smart wearable airbags have been developed to mitigate motorcyclist trauma and are becoming an increasingly popular protective equipment among professional riders as well as everyday riders. The aim of these safety devices is to inflate an air cushion around the human body to absorb the energy of the impacts. The inflatable bags are embedded in the garments worn by the motorcyclists, such as a vest, a jacket or a leather suit. All electronic components and the inflator, allowing the detection of a fall or a crash and the inflation of the airbag, are also integrated into the garment making the protector bike-independent [1].

Smart wearable airbags, covering at least the shoulders, are mandatory in MotoGP World Championship since 2018. The use of this technology led to a significant reduction of clavicle fractures [1] and provides accurate data of the accident based on recorded linear accelerations and angular velocities [2]. High-side falls are characterized by a sudden and violent rotation of the motorcycle about its longitudinal axis. They occur when the rear tire starts to lose traction in a turn, slips laterally and then suddenly regains traction, flipping the motorcycle toward the outside of the corner and catapulting the rider. This accident scenario is not frequent, but could be severe for track and road riders [3-6].

The objective of this research is to investigate the dynamics of motorcycle riders during high-side falls, based on videos, airbag data and medical reports, in order to improve the design of protective equipment.

2. Materials and methods:

High-side falls of MotoGP World Championship riders wearing In&motion airbag technology were studied. Three main sources of data were used in this work: Videos of the falls, the signals measured by the airbag during these accidents and the medical information of the riders after check-up in the medical centre of the circuit.

2.1: Videos:

Video footage available on MotoGP's website and social media were examined to determine the duration of the accident and identify the impacted zones of the torso. The torso includes the thorax, abdomen, pelvis, back and shoulders.

Time instants when the rider is ejected by the motorcycle ($t_{EjectionVideo}$) and when the torso impacted the ground ($t_{ImpactVideo}$) were identified on the video. The duration of the fall (T_{Fall}) was defined as the period of time between the ejection of the rider and the impact against the ground.

2.2: Airbag data:

Leather suits equipped with In&motion airbag technology includes the In&box, an electronic box that houses the sensors and algorithms, which is positioned in the rider's hump (Figure 1). It has 6 on-board sensors (3 accelerometers and 3 gyroscopes) to monitor the dynamics of the rider. This data is cross-referenced and processed by predictive algorithms, enabling the system to detect a fall and trigger the airbag if necessary.

a)

b)

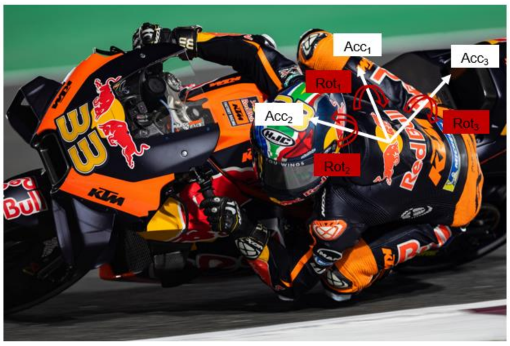


Figure 1. a) The In&box. b) Location of the In&box and orientation of the 6 sensors.

The data collected by the airbag during high-side falls was used to determine the instant of airbag triggering ($t_{Activation}$). The instant of time when the rider impacted the ground was defined based on a sudden raise of the resultant acceleration measured by the airbag ($t_{ImpactSignal}$). Then, the beginning of the accident ($t_{EjectionSignal}$) was identified going backward a time of T_{Fall} from $t_{ImpactSignal}$. The period of time for airbag activation from the beginning of the accident ($T_{Activation}$) was calculated as the time between $t_{EjectionSignal}$ and $t_{Activation}$.

The variables calculated from videos and airbag data are summarized in Table 1.

2.3: Falls reports:

Falls reports provided by MotoGP championship were analysed [7-9]. These documents include data about each accident such as the rider, circuit, corner, date, time and injuries. Information about injuries is updated on event date based on tests carried out in the medical centre of the circuit. The complete injury description is not available as riders usually undergo further medical tests outside the circuits.

Table 1. Variables defined by synchronising video footage and airbag data.

Variable	Definition	Source
$t_{EjectionVideo}$	Instant of time when the rider is ejected by the motorcycle	Video
$t_{ImpactVideo}$	Instant of time when the torso of the rider first contacts the ground	Video
T_{Fall}	Duration of the fall	$T_{Fall} = t_{ImpactVideo} - t_{EjectionVideo}$
$t_{Activation}$	Instant of time when the airbag is activated	Airbag trigger signal
$t_{ImpactSignal}$	Instant of time when the torso of the rider first contacts the ground	Airbag resultant acceleration
$t_{EjectionSignal}$	Instant of time when the rider is ejected by the motorcycle	$t_{EjectionSignal} = t_{ImpactSignal} - T_{Fall}$
$T_{Activation}$	Period of time to activate the airbag	$T_{Activation} = t_{Activation} - t_{EjectionSignal}$

3. Results:

This work focused on the analysis of 5 high-side falls captured on video between 2020 and 2022. The total accident duration, the time to activate the airbag from the beginning of the accident, the first impacted torso region against the ground, the maximum resultant acceleration measured by the airbag during the impact with the ground, if the rider was transferred to the medical centre of the circuit and the injuries sustained by the rider were studied and reported (Table 2).

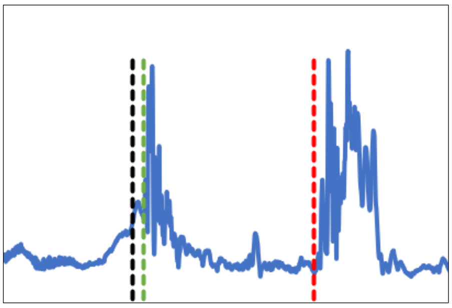
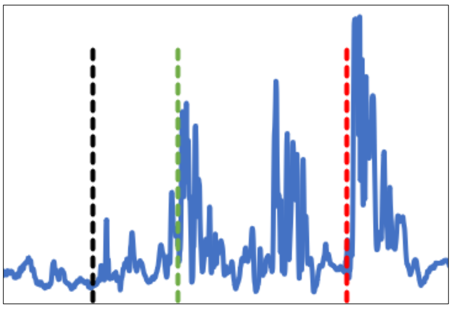
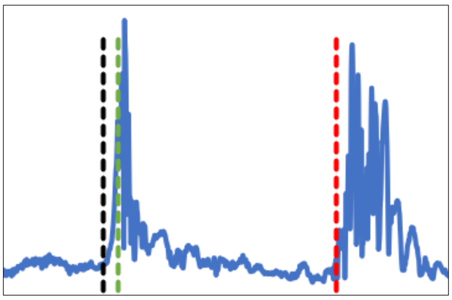
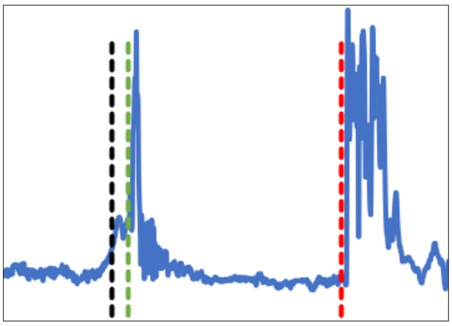
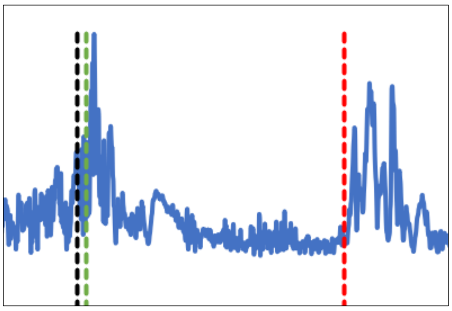
Table 2. Main results of the analysis of the 5 high-side falls.

Fall	T_{Fall} (ms)	$T_{Activaton}$ (ms)	First torso impact	Acceleration peak (G)	Medical centre	Injuries
1	721	46	Upper back	26	Yes	No
2	899	299	Right shoulder	28	Yes	No
3	820	55	Upper back	24	Yes	No
4	799	59	Upper back	28	No	No
5	1030	35	Buttocks	19	Yes	Left hand and foot fractures

The duration of the falls, from rider ejection to ground impact was between 721 and 1030 milliseconds (ms). In three accidents, the first impacted area of the torso was the upper back. In the two others, the rider fell on his right shoulder and on the buttocks. The maximum resultant accelerations measured by the airbag during these impacts ranged from 19 to 28 G. The airbag triggered between 35 and 299 ms after the ejection of the rider and protected the upper torso in all the studied falls. In fall 2, the rider was still taking hold the handlebars some time after being ejected upwards by the motorcycle which explains the higher activation time for this accident. After the falls, four riders were transferred to the medical centre of the circuit and one of them had fractures on his left hand and foot.

Table 3 shows the time instants identified from the video analysis and the resultant acceleration curves measured by the In&box.

Table 3. Time instants identified from videos and airbag data.

Fall	Video screenshots		Airbag data
	$t_{EjectionVideo}$	$t_{ImpactVideo}$	**Blue: Resultant acceleration** **Black:** $t_{EjectionSignal}$ **Green:** $t_{Activation}$ **Red:** $t_{ImpactSignal}$
1			
2			
3			
4			
5			

4. Conclusion:

A new methodology based on the synchronisation of real accident videos and airbag data was proposed in this work for the analysis of high-side falls. Information about chronology, impact location and impact severity was obtained from 5 MotoGP accidents and could be used to improve the effectiveness of wearable airbags and other safety devices.

Considering the studied cases, the airbag should detect the accident and inflate in less than 720 ms to protect the rider against the first ground impact. Current airbag technology showed good fall detection performance with much lower activation times than the total accident duration. Based on the first impacted regions of the torso with the ground, the protection of the back and the shoulders seems necessary which is coherent with the minimum protective areas defined in the 2018 FIM airbag regulation [10] and the traumatology observed in circuit racing [11]. Focusing on impact attenuation, riders with the airbag were exposed to decelerations up to 28G, but no injuries on the areas covered by the airbag were reported. Further data, including cases leading to torso injuries and others without airbag, would be useful to better understand injury mechanisms and human tolerance.

This research could be a good basis for the development of a standard, currently non-existent, to evaluate accident detection performance of electronic airbags. A similar approach could be applied to accidents on the road, where high-side falls are underreported and airbag data could be useful to identify and better understand them.

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