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AUTO+ MEDICAL

FAST ASLEEP

How racing drivers beat fatigue and jet lag with science

AUTO+MEDICAL

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Welcome to the new issue of AUTO+ Medical, featuring the latest news from the world of motor sport medicine.

In our cover story, we take a medical look at how drivers deal with jet lag and tiredness when competing in global motor sport, often crossing continents on a weekly basis.

We speak to my friend and FIA Safety Director Laurent Mekies about his important work in motor sport. We also take a look at the evolution of rescue teams in racing, and the challenges they face today in cutting open the super-strong cars of modern times.

We go inside the Medical Facility at Circuit Paul Ricard, and see how the medical team is preparing for the return of the French Grand Prix, after a decade off the Formula One calendar.

In our Road Back feature, we speak to IndyCar Series race-winner Sébastien Bourdais about his high-speed accident during Qualifying for the 2017 Indy 500, and how he recovered from it.

Finally, in our Scientific Article, we take a look at the increased incidence of concussions in motor sport, and the importance of understanding the condition.

I hope you enjoy the latest issue.

Prof. Gérard Saillant,
President, FIA Medical Commission

LETTERS

In this section, we print the best letters and emails received from readers around the world. We welcome comments on articles as well as suggestions for future content. If you wish to send in a letter or email, please direct it to: medical@fia.com

Dear Editor,
Earlier this year, I was involved in a multi-car accident at Croft during qualifying for the fifth round of the British Touring Car Championship (BTCC).
The accident began at the entrance to the Jim Clark Esses and finished 400 yards later on the exit of Barcroft, the fastest corner on the circuit.
Prior to that moment, in truth, I was unaware of the real risks that I was taking every time I went out on track. I think those close to me and even the wider BTCC community did not anticipate such an accident in this day and age.
Thinking back to the start of the year, I was so ignorant I even assured my girlfriend that an accident causing serious injury would be almost impossible.
However, an unfortunate set of circumstances led to a serious accident occurring, which in turn resulted in myself and two other drivers sustaining wide-ranging injuries. The urgency and pressure put on the medical staff of the BTCC must have been immense.
I can report with confidence that the common paddock joke of extraction team members, Doctors and ambulance drivers being on site to keep coffee and biscuit supplies under control, is indeed a complete myth!
My memory of the second part of the crash and the aftermath is minimal.
That is a very key point in what I would like to put across. I believe that in situations like the accident at Croft, we are completely in the hands of the amazing professionals who give up their weekends to ensure our safety.
I did not know what happened when a cutting team is called out. I did not know how to maintain a calm and steady position once my lungs had punctured and limbs had broken whilst still trapped inside the car. It was completely down to the professionalism of the extraction team and medical staff not only to get me out of there safely and quickly, but to achieve all that whilst guiding me through every step and assuring that I remained in a stable and cooperative condition.
I cannot fathom the pressure they must have worked under. Especially when one considers the fact that this pressure was threefold. Three drivers, three sets of families, friends and loved ones, teams and supporters. In the hours, days and weeks after the accident, the support remained for not just the drivers but their families too. The affect this had on my loved ones in particular cannot be underestimated. Dr Paul Trafford's words of comfort to my Dad instigated a feeling of stability and security which was key to my recovery and my family's sense of wellbeing.
The actions of those urgent minutes have a lasting affect on all involved.
For me, I count myself so lucky that I was in the hands of the BTCC medical staff. I have attended all but one of the BTCC races since the accident and I feel such a bond with staff who I am ashamed to say, I don't even know the names of. Yet they are still there, eating their biscuits and drinking the coffee, absolutely ready for the next time something like this unfortunately happens.

Luke Davenport
Driver, British Touring Car Championship

Dear editor,
Following the excellent feature in the last issue about Fire Simulation Training, I wanted to raise another important point about firefighting in the motor sport environment - respiratory protection.

When we speak of vehicle fires today, at least from a respiratory protection standpoint, the best practices approach from a worldwide perspective:

"Don positive pressure self-contained breathing apparatus during suppression operations and also during post suppression overhaul operations while smoke and vapor & particles are present"

Well that's basically the entire event. However, this is on public roads, streets, highways, motorways etc. What of motor sport? We rarely ever see Self-Contained Breathing Apparatus (SCBA) at a motor sport venue. At least not seemingly beyond tokenism.

Why is this? I watched the Australian GP and one of the Haas F1 cars came in with an apparent fire in its engine bay. No visible fire but quite a bit of smoke. When the car stopped and as the driver started to exit the vehicle there were 2 pit road firefighters with dry power extinguishers and 3 Haas crew members with Foam APW extinguishers at the vehicle with the Haas crew actively putting agent onto the vehicle.

Good job by all, at least by appearances especially with what looked like a wetting agent not a foam! But not one person had any form of respiratory protection. Most of you will say "those cars don't have a large fuel load". Really? Besides carrying enough fuel for entire race there's a high energy battery, most of the body is made from composite material of one kind or another and combustible alloys. The smoke also hides various acids and gases that are toxic to breathe.

When dealing with car fires on public roads, SCBA is worn during suppression and overhaul operations basically whenever there is a possibility of smoke, vapors and particles released into the air. So why not at a race track?

Cost and logistics can be a consideration for both the initial outlay and subsequent upkeep. A frequent argument is that such an investment is overkill for how often a significant fire occurs. Does that go for "a little" bit of extrication as well? Polymers, plastics, composites, combustible alloys and related materials are bad news in a fire. But had anyone done any real research into this issue of Personal Protective Equipment (PPE) for responders and especially respiratory protection in the realm of vehicles fires?

There is quite a bit of material about passenger vehicle fires where the amount of toxins, acids, toxic particulates and hazardous dusts can be significant. In all of the studies, SCBA has been an essential recommendation for personnel at these incidents.

Admittedly, while one can wear SCBA at the track, there are events that are at least 2+ hours in length for instance endurance races that may be 12 or 24 hours long. This additionally means that many spare air cylinders are needed ready for swap.

So are there options instead of SCBA? Here are some options.

The first is a mask from Respiro called FB-1. It was designed for the fire service in the UK and for the overhaul period post structure fire. It was also designed to be proof against dust and particles at a motor vehicle crash. The mask was able to be donned and doffed with all PPE in place due its Velcro closure and it has two replaceable filters in the front.

A second option is a RZ mask designed for the public safety environment. The filter is above the grade of an N95 with active carbon fiber filtration for chemicals as well as for dusts & fibers plus just like the FB-1 mask it has replaceable/changeable filters. We really do not have any PPE now in use at motorsport events to protect our respiratory tract. Along with this we need to take a serious look at research into PPE in the motor sport environment. We need to demonstrate for real not theorize what is hurting us short and long term. We need to strive to make improvements in all areas of our PPE but especially in the area of respiratory protection.

David Dalrymple AIETecRI
FF/EMT/Rescue Technician, Clinton EMS/
Rescue/Fire Technician, American Rally Association

GLOBAL NEWS

Luke Davenport sustained severe injuries, but has returned to the cockpit after five months.

RACERS RETURN FROM INJURY

A number of top drivers have returned to racing in recent weeks following injury.

One of the most notable comebacks has been made by British Touring Car Driver Luke Davenport, who returned for the first time since a crash in June left him in a coma.

He sustained major injuries during Qualifying at the Croft Circuit, when an oil leak sent him and several others off-track. Davenport crashed into fellow racer Jeff Smith, and suffered a shattered pelvis, a broken right leg, broken right arm, and chest and lung damage, before being placed in a medically induced coma for several weeks.

He completed 10 laps of Snetterton circuit on 7 November, driving a Motorbase Performance-run Volkswagen Golf TCR.

Though he has a cage screwed to his pelvis, a plate to protect his damaged shoulder, and a rod inserted into his leg, he reported there was "no physical pain".

He is aiming to be back to fitness for the 2018 season, where he hopes to compete again for Motorbase Performance. The first round of the season is at Brands Hatch on 7-8 April.

NASCAR racer Aric Almirola made a return to racing in the New Hampshire NASCAR Cup race following a back injury sustained earlier in the season.

Almirola suffered a partially crushed vertebra in his back when he slid into Joey Logano's stricken car at Kansas Speedway in May. The Richard Petty Racing driver however has since made a full recovery.

IndyCar star Sébastian Bourdais, meanwhile, returned to the cockpit in a mid-season test at Mid-Ohio after suffering a fractured pelvis, hip and two broken ribs during qualifying for the Indianapolis 500. *See Page 34 for a full interview with Bourdais about his return to racing.*

WILLIAMS DEVELOPS 'BABYPOD'

Williams Advanced Engineering has utilised F1 technology to develop a high-tech infant transportation capsule for carrying babies to hospitals.

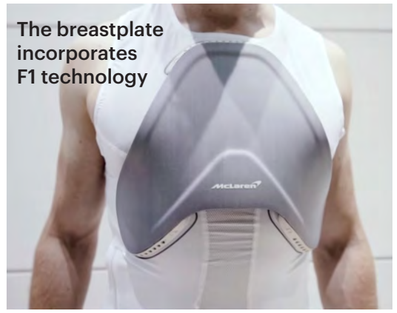
The 'Babypod 20' is a lightweight box with a transparent lid, ensuring safe transportation of critically ill babies to hospital.

The outer casing is made from carbon fibre, a technology used in the design of Williams' Formula One cars, and the inside is padded to ensure comfort for the infant within.

Babies require very careful transportation with minimal vibration or noise, and must be kept at constant temperatures. The Babypod 20 ensures all these criteria are met, and the transparent lid allows close inspection for medical staff.

The device weighs 9.1 kilograms and costs £5,000, and is already being used by Great Ormond Street Hospital in London, with plans to market it more widely in the future.

The carbon fibre casing shares Williams F1 DNA.



The breastplate incorporates F1 technology

MCLAREN DEVELOPS 3D PRINTED MEDICAL BREASTPLATE

McLaren's advanced technology arm has developed a bespoke 3D-printed wearable breastplate to protect internal organs.

Named 'Project Invincible', McLaren Applied Technologies designed the product to protect the thorax region of the body, ultimately acting as an exoskeleton in place of the rib cage.

Commissioned by an anonymous client following thorax surgery, McLaren measured his chest region via 3D scanning, ensuring that the plate would fit perfectly to the contours of the body, protect from impacts as well as transfer and attenuate forces away from the affected region.

The client's surgery had left him with a compromised left rib cage, sternum and kidney, and living in fear of causing further injury to the body by performing simple everyday tasks.

The device was created through a collaboration involving multiple divisions of the company, along with Stratasys, a 3D-printing manufacturer with whom McLaren has been working to print pieces for its Formula One cars.

The plate was made from a lightweight composite made from Dyneema fibers, which are used in body armour, for damage containment, plus a tough resin with woven fabrics for impact resistance. Zylon fibres, which are used in F1 cars, and stiff carbon fibres, were also incorporated.

FIA LAUNCHES COMMISSION FOR DISABLED RACING

The FIA is creating a Disability and Accessibility Commission to advise on strategies to encourage and allow participation in motor sport for people with disabilities.

Motor racing is one of the few sports where disabled drivers compete alongside able-bodied drivers. This was demonstrated by quadruple amputee driver Frédéric Sausset, who completed the 2016 Le Mans 24 Hours Race.

Another driver, Nathalie McGloin, became the first female with a spinal cord injury to be granted a racing licence in the UK. Speaking recently at the FIA Sport Conference, she talked about the importance of ASNs adapting their regulations to ensure inclusivity.

"The MSA in the UK is looking at improving the process for injured people to pass their race licence. For me, having someone assess your abilities directly is key."

She also highlighted the importance of maintaining the highest safety standards, adding: "These regulations need to be put in place to demonstrate that disabled racing is safe racing."

The new commission will aim to encourage even more disabled drivers to compete in motor sport.

BIOMETRIC GLOVES SET TO BE INTRODUCED INTO F1

The FIA is set to introduce a new race glove into Formula One that sends potentially life-saving data from driver to medical crew.

Stitched into the glove is a flexible sensor, measuring just 3mm in thickness. It is the sport's first biometric monitoring device and is set to be inserted into every drivers' gloves next season in a bid to monitor their vital signs during the race.

The project, which is being supported by the Global Institute for Motor Sport Safety, has been led by F1 Deputy Medical Delegate Dr Ian Roberts and F1 Medical Car Driver Alan van der Merwe.

"We know that the monitoring of people is essential in terms of their medical care," said Roberts. "Drivers in incidents are no different. We would like to start monitoring and assessing them as soon as we possibly can. But the equipment that we currently use is relatively bulky and is only applied after the incident has happened. There are also times when the driver isn't immediately accessible to us, so if we can't see him or we're not actually next to him, there's limited information that we can get."

F1 driver Carlos Sainz's accident during the 2015 Russian GP is a case in point. The Spaniard lost control of his Toro Rosso at Turn 13 during the third practice session and hit the barrier head-on at 153km/h. Fortunately, he was unhurt but it was difficult for the F1 medical team to know this, as part of the barrier came to rest on top of him. When they arrived at the scene, they had to wait until the barrier was removed before knowing the extent of his injuries.

"Accurate monitoring was impossible until we got hands-on, and obviously we couldn't do that until the barriers were moved," says Roberts. "If we had monitoring on him immediately, we could have planned our rescue even better than we did.

The gloves will be ubiquitous for the 2018 F1 season, measuring signs of all drivers.

With this new technology, as soon as a driver has an incident we will receive physiological readings and biometrics, so he is continually monitored from point zero, through to the initial response and on to the medical centre."

Initially the devices will use an optical sensor to measure 'pulse oximetry', or the amount of oxygen in the blood, alongside the pulse rate.

"That gives us the most 'bang for buck'," says Van der Merwe. "Pulse oximetry is one of those metrics where for a little information, you can deduce quite a lot. You can change what you are doing in a rescue scenario based on that one metric."

F1 is just the first step for the device in motor sport as the idea is to filter down the technology to other championships, with the help of the Global Institute.

"The Global Institute has been instrumental in allowing a project like this to take shape, to give us the avenues to have access to the teams and track time," adds Van der Merwe.

Going forward, there are plans to implement sensors for respiratory rate and temperature. In addition to the safety benefits, these will help teams and drivers with performance monitoring.

"They're the next two big things," says Roberts. "Respiratory rate gives a very good indication of a driver's state of health and stress, while temperature is well known for affecting performance. They are the two for us that we're going to be looking at more than any others."

WTCC STAR SIDELINED AFTER TESTING CRASH

Honda World Touring Car star Tiago Monteiro was left hospitalised following a test crash at Barcelona.

Monteiro suffered 255kph crash at the Circuit de Catalunya while testing for the Honda WTCC team during the mid-season break.

The Portuguese driver's brakes failed as he approached the first corner, sending his Honda Civic backwards into the safety barrier, with the impact leaving him temporarily unconscious.

Monteiro was extricated from the car having regained consciousness and assessed in the circuit's medical centre. Having complained of concussion, two blood clots were discovered in his neck, affecting his vertebrae and vision, as well as bruising to the left side of his body.

In an interview with Eurosport following the crash, Monteiro spoke about his condition immediately after the incident: "The main issue I had was the concussion in my head with two blood clots. Then the vertebrae, the eyes and the nerves, that were squeezed by the blood.

"If there was just a little more blood or a bigger tear in my neck I would have been unable to move, or even worse. I was very lucky."

Monteiro remains sidelined from action and has been ruled out of the final round of the season in Qatar on 1 December.


Monteiro is set to miss four rounds.

TWELVE HOSPITALISED AT DRAG RACING EVENT

A dozen spectators were taken to hospital after a competition car sprayed burning fuel into a crowd at a drag racing event in Australia.

The incident, which took place at Alice Springs Inland Dragway on 4 September, occurred when the driver of the car began doing burnouts close to a fence, behind which hundreds of fans were standing.

Fuel then sprayed out of the car and ignited. Twelve people were injured in total, including a 48-year-old man and his 19-year-old son. Both suffered burns on 20 per cent of their bodies, including on their faces.

The Royal Doctors Flying Service transferred both men, as well as another two spectators, to Royal Adelaide Hospital for treatment, more than 1,500 kilometres away.

The event was subsequently halted to allow for proper medical intervention to those involved.


FACEBOOK

NEW AMBULANCE FOR ISLE OF MAN MOTOR SPORT

The Isle of Man's Hogg Motorsport Association has taken delivery of a new Peugeot ambulance as part of its plans to phase out its older vehicles.

With help from The Manx Lottery Trust, a delegated partner of the Big Lottery Fund, The Hogg Motorsport Association was awarded a grant of £30,000 towards the total cost of £76,299.

With its current emergency rescue vehicles now more than ten years old, the new ambulance represents the first step in the Association's rolling plan to replace its rescue vehicles with more modern ones over the next two to three years.

The rescue vehicles are staffed by the Hogg Motorsport Association, a group of 17 volunteers who attend more than 130 motor sport event sessions per year, including the prestigious Isle of Man Tourist Trophy.

As well as serving as a dedicated rescue outfit for motor sport competitors and spectators around the Isle of Man, the ambulances are also occasionally called upon to support the ambulance service.

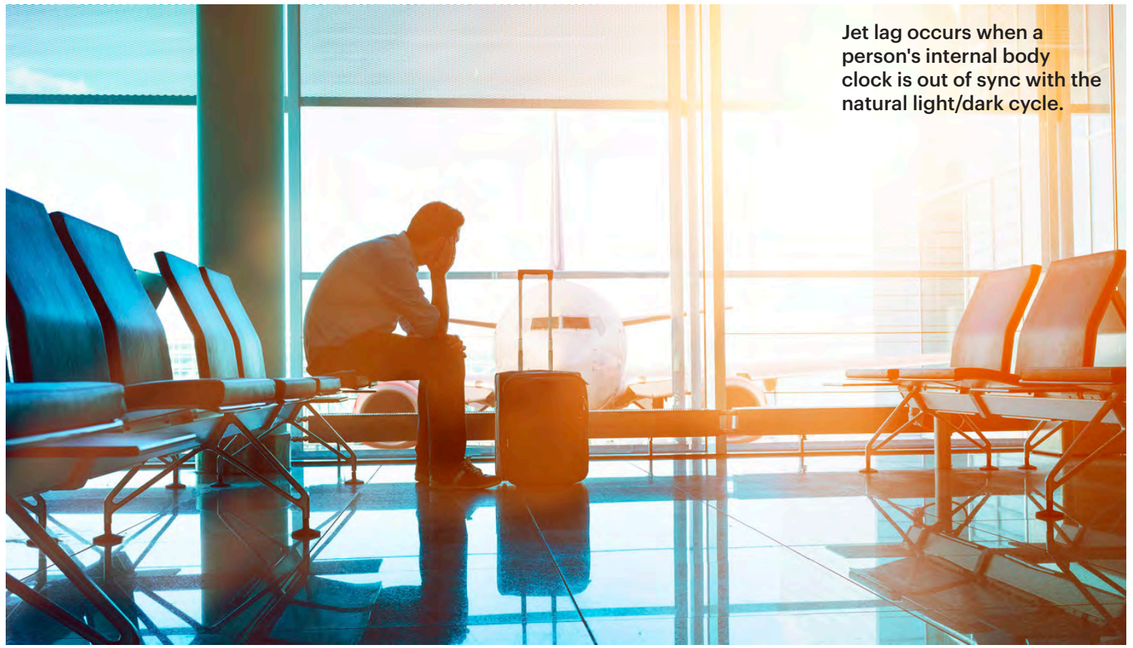
Hogg Motorsport is aiming to update all three of its ambulances.

AUTO+MEDICAL FEATURES

FEATURES

FAST ASLEEP

How racing drivers in global series use scientific sleeping plans to stay alert and avoid jet lag



Jet lag occurs when a person's internal body clock is out of sync with the natural light/dark cycle.

It doesn't matter whether you work in an office, on a construction site, or behind the wheel of a racing car capable of hitting 200 miles per hour – the benefits of a good night's sleep are universally acknowledged.

Racing drivers today arrive at racetracks all around the world several days in advance, to take part in PR events, team activities, training, practice and qualifying, as well as the race itself.

These hectic schedules are carefully planned and managed by team personnel, but to ensure they don't have a detrimental effect, some racing drivers and teams are now using careful plans to manage their sleep too.

Dr Steven Lockley, a leading neuroscientist in the Division of Sleep and Circadian Disorders at Brigham & Women's Hospital in Boston, Massachusetts, is one of the experts working with F1 teams and drivers. Working with Hintsa Performance, Dr Lockley has advised on and formulated individual sleeping plans for Mercedes AMG Formula One team, ensuring that they get enough shut-eye, and avoid dreaded jet lag when travelling over multiple time zones.

"The travel schedule is quite brutal," says Dr Lockley. "They travel long distances potentially every two weeks, and that causes problems with jet lag, because the body clock can't reset quickly enough to the changing time zone.

"I provide plans to the drivers' coaches, who then work with the drivers to help speed up the rate of adaptation to the new time zone. If you don't do anything proactively, you only shift by up to an hour a day. For example, London to Melbourne is an 11-hour time difference, which could take 11 days or longer to adapt to without specific advice. This is too long to be ready for the race, so we've developed a programme which speeds it up to about three hours per day. If you start shifting before you leave, you can be pretty well adapted within a few days of arriving, even with these long trips with a big difference in time zones."

RHYTHM IS THE ANSWER

The circadian rhythm is an internal body clock that is roughly 24 hours in length, and sets us on a daily schedule, letting us know when to sleep, wake, and be active. Modifying this to fit with new times zones, as Dr Lockley explains, is the key when it comes to avoiding jet lag.

"The pattern of light and dark helps shift the clock more quickly, so we advise when to see light - either sunlight or bright, indoor lights - and when to avoid it, by wearing sunglasses or not being in natural light. We also offer advice on melatonin treatment, which does two things. It shifts the clock, and also helps you sleep at the 'wrong' time when travelling, so it's very good at helping to increase the rate of adaptation.

"In addition we include naps in the schedule to help alleviate some sleepiness, as well as caffeine advice to maximise alertness while minimising its negative effects on sleep. Caffeine doesn't affect the clock, but it can help you stay awake at times when we want people to see light."

These may sound like simple steps to follow, but Dr Lockley explains that tailoring these tips for each driver is of paramount importance, as well as following the guidelines at set times.

> **"IF YOU DO NOTHING PROACTIVELY, YOU ONLY SHIFT UP TO AN HOUR A DAY...WHICH WILL TAKE TOO LONG TO BE READY"**

Dr Lockley's methods were first used to acclimatise NASA astronauts.

"We also ask about people's sleep habits, duration, their sleep timing, whether they're a morning or evening type, and assess some of the other factors that might affect the schedule, and put them all together in one plan. It's individualised for drivers so it fits into their schedule and their biology."

TURBO LAG

There's an oft-used phrase that when travelling on a plane, 'West is best, East is a beast'. Put simply, travelling in a Westerly direction is easier for most people, because it's following their natural circadian cycle.

"The direction of the travel also makes a difference," adds Dr Lockley. "Most of us find it easier to travel West, because most of us have a body clock that is slightly longer than

Sometimes not even a strong energy drink can counter the effects of jet lag

24 hours, but around a quarter of people find it easier to travel East, because their body clocks are slightly less than 24 hours.

"The extent of the challenge depends on the number of time zones, and also on the internal body clock. When you're looking at solutions for jet lag, you don't have to necessarily shift the clock in the direction the calendar says."

Although the preference of Easterly or Westerly travel can have a big effect on the overall plan, it's sometimes far easier to head the other way around the globe to save time, and reduce the number of time zones travelled through.

"If there's a difference of 14 hours in one direction, there's a difference of 10 hours in the other direction, and you caan travel in either direction. When you're planning, you can work out the shortest distance in biological time, and shift the clock according to that."

MULTI-TASKING

As well as the physical and mental demands of racing for hours at a time, professional drivers today often compete in more than one series, taking them to all corners of the world in a very short space of time.

"I FIND TRAVELLING EAST IS THE HARDEST THING, COUNTRIES LIKE HONG KONG, MACAU AND JAPAN ARE DIFFICULT TO ADAPT TO"

This year, Swedish driver Felix Rosenqvist raced in the FIA Formula E championship, a series spanning five continents, as well as the full 2017 Japanese Super Formula season, held exclusively in Japan. This meant he had to criss-cross the globe on numerous occasions.

"I've been travelling a lot to Japan this year, nine times in total," he explains. "With Formula E, there are many races on different continents, and I mainly find that travelling East is the hardest thing, so countries like Hong Kong, Macau, Japan are very difficult to adapt to."

Despite racing in two elite motor racing series, Rosenqvist says that the days leading up to an event are no time to relax, lest you suffer the negative effects of jet lag.

"It's important to stay busy. Let's say you arrive on the Monday and race on Friday, Saturday and Sunday - you should try to stay busy to get into a normal rhythm.

"I think the best thing to do is to follow the day, as in when the sun goes down or when the sun goes up, you sort of need to see it, so it calibrates your brain to the new time zone."

Dr Lockley's research confirms that the light/dark cycle is the most important factor with which to reset a person's circadian rhythm to a new time zone, although he says the timing of this must be planned correctly to avoid making jet lag worse.

"The light/dark cycle is the major environmental time cue that sets your clock every day, so that you're synchronised with the 24-hour world," says Lockley. "As soon as you start to adjust those light-dark cycles and sleep-wake cycles, you're going against

Nico Rosberg says he "slept perfectly and had no jet lag" thanks to Dr Lockley's advice.

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your clock, and then you get problems. If you fly to Japan and try to sleep at a time when the brain is promoting wake, you'll have very poor sleep in Japan, and then when you try and stay awake, you'll have very poor quality wakefulness."

Rosenqvist's packed 2017 schedule included several back-to-back weekends in different parts of the globe, with one week incorporating trips to Spain, Japan, and the USA. However, he feels that a relatively short stay in Japan helped prevent any negative effects.

"We did a Formula E test in Spain in the simulator in preparation for the New York ePrix, which was on the Wednesday or Thursday before the Fuji race. Then I arrived in Fuji on the evening before free practice, so that weekend was quite crazy!

"I actually felt quite good, because the time I was there was really short. It's almost like two different theories - you either stay really long so that you get adapted or you just deal with it for a short period of time. Afterwards I set off straight to New York and I think I arrived there on Tuesday morning, and somehow, I was just immediately into the time zone in New York, so that was actually one of the easiest adaptations for jet lag."

WINNING FORMULA

One of Dr Lockley's main pieces of advice is to begin shifting the body clock before travelling. Nico Rosberg, 2016 FIA Formula One World Champion with Mercedes AMG, feels that these sleeping plans directly and positively influenced his title challenge.

"I always struggled through the years with sleeping when I got to different time zones," said Rosberg in a recent interview for UBS.

"The team got advice from [Dr Lockley] and

"I HAD THAT LITTLE BIT EXTRA BRAIN POWER... I'M SURE THAT'S PART OF WHY I WON THE WORLD CHAMPIONSHIP"

it revolutionised my life. The advice he gave was to do it all in small steps, a maximum of one and a half hours per day, six or seven days before you get to the new place. I just slept perfectly and had no jet lag whatsoever. I had that little bit extra brainpower and energy. Anything extra you can bring to the table is going to help you, and I'm sure that's part of why I won the World Championship."

But adjusting to a new time zone early doesn't work for everyone, and is one of

Rosenqvist experienced a 14-hour time zone shift, but managed a podium either side of it.

Sunglasses at night might look odd, but it can help drivers adapt to new time zones.

the challenges that Dr Lockley sometimes encounters when putting together a plan.

"If a driver has got commitments back in Europe, where it means they can't start shifting their clock early, then we have to work around those issues."

Rosenqvist is one such driver, who says that he has tried to adapt to a new time zone ahead of arrival, but it's not for him.

"I've tried to get into the time zone before travelling, but it rarely works for me, because you have other things to do at home. If you start going to bed early before leaving home, you sort of jeopardise your whole other life."

Racing drivers are all different, so there's no 'catch-all' solution for avoiding jet lag or dealing with it, but with these personalised sleeping plans, they have very good chances of adapting to new times zones.

QUICK TIPS

Tips to give you the best chances of beating jet lag and sleeping better.

JET-LAG

- **Start adjusting your sleep schedule before travel**
- **Establish whether you prefer travelling West or East and plan journeys accordingly**
- **For long journeys, try to travel the shorter distance in biological time**
- **When you arrive, synchronise your circadian rhythm with the light-dark cycle by seeing as much of the natural light as possible in the day, and avoid light when it's dark**

GENERAL SLEEP

- **Cool, calm, comfortable and quiet room**
- **Use eye masks and earplugs to block/reduce external stimuli**
- **Avoid screens before bed as these emit a lot of alerting blue light**
- **Breathing exercises can help calm the brain before sleep**

LAURENT MEKIES

FIA Safety Director
Formula One Deputy Race Director
Global Institute General Manager, Research

Laurent Mekies is a man of many titles. The former Chief Engineer of the Toro Rosso F1 team joined the FIA as Safety Director in 2014 and has since added roles as F1 Deputy Race Director and Global Institute General Manager, Research. But, as he explains to AUTO+ Medical, they all complement each other to help support one of the FIA's main objectives - improving safety in motor sport.

Mekies joined the FIA as Safety Director in December 2014

AUTO+Medical: It has been three years since you became FIA Safety Director. How have you found the role?
Laurent Mekies: The role is fantastic, that's the simple truth. After having spent so many years trying to chase lap times for Formula One teams, it's difficult to try and find a better motivation than to contribute to the safety of the sport. We have a great team in Geneva, we have impressive support from the commissions related to the safety effort – from the Medical Commission, from the Circuit Commission and of course from the Safety Commission – and at the end of the day these have allowed us to move things relatively fast. People often think things are going slower in a big institution like the FIA but ultimately you can pull things through and make things efficient here thanks to all the good people and the willingness there is in the structure. And when we don't go about it in a fast enough and efficient enough way, the FIA President is the first to push us to perform better.

A+M: You are also General Research Manager of the Global Institute. How does this tie in with your FIA role?
LM: I think it's completely integrated really. It's about one safety effort from all the various elements connected to the FIA. Everybody contributes to it and we try to be as synchronised and as efficient together as possible so the integration of the safety research effort into this big picture is fundamental. There is a great group of researchers who are very, very skilled and experienced, we have super high-level people there and it has been an enjoyable effort to put all that together.

> **"IT'S HARD TO FIND A BETTER MOTIVATION THAN TO CONTRIBUTE TO THE SAFETY OF THE SPORT"**

A+M: In addition, you are Deputy F1 Race Director. How does that fit in?
LM: Of course on paper it's two different things – one is a sporting job and one is a safety job – but in reality having the link between the two is giving us a lot of advantages on the field. Back in Geneva when we try to support the departments and all the

Working with a Formula One team for several years gives Mekies a unique perspective on safety

categories of motor sport with the safety side, it allows us to have a direct, hands-on experience on one of the championships. In F1 we have all the firepower to develop new things and therefore it's a good accelerator for projects, especially on the research side. So this is very valuable for the safety effort. We also have a similar hands-on experience in other championships with our safety delegates.

A+M: You used to work for an F1 team, and now you've moved over to the governance side. Is there anything that has surprised you from this different perspective?

LM: I wouldn't say surprised, because in the end we are all in the same circus! Really we are all working for the sport and it's simply that we're looking at it from a different angle. But at the end of the day it's the same faces so it's quite easy to step from one role to another because it is a small community, and therefore it makes things very easy. I guess the biggest surprise is that you are able to move things forward quite fast at the FIA, nearly as much as in the teams. It has been great to see that with everybody's contributions and willingness, you can push things through.

A+M: Speaking of pushing through, we've got the halo introduced to F1 for next year. Is this taking up a large part of your time?

LM: The Halo is one of our many safety research projects, but of course it is one of the most highest profile ones. So yes it took enormous energy from the researchers to first complete the research work, and then once the research work was complete to try to make sure we can deploy it in a very tight frame that we have from the decision to the start of the racing season next year. On top of that, we are deploying it in as many categories as possible every time a new car is coming out. In 2018, we'll have a new Formula 2 car, Formula E will have a new car for season five, in 2019 Formula 3 will have a new car... So yes, it has taken a lot of the research group resources in the last 5-6 months, but I would say that more globally the additional frontal protection project has been one of the key pieces of research of the last seven years, and has been central to the research work.

> **"MY ROLES ARE COMPLETELY INTEGRATED - IT'S ONE SAFETY EFFORT FROM VARIOUS ELEMENTS, CONNECTED TO THE FIA"**

Safety training is "fundamental" for marshals

A+M: Halo is going to have huge safety benefits, but what are the other considerations for bringing in this device?

LM: It's like for anything, the development is in the detail. So we are trying to iron out all the items that are now passed to make sure we have as smooth an introduction as possible for such an important change. We are looking into the extrication techniques, we are looking at the training for the marshals, we are looking at a large quantity of perhaps small items that together will make the difference between a smooth deployment and a difficult deployment.

A+M: Has there been extra training for F1 marshals and has this been carried out or overseen by the FIA?

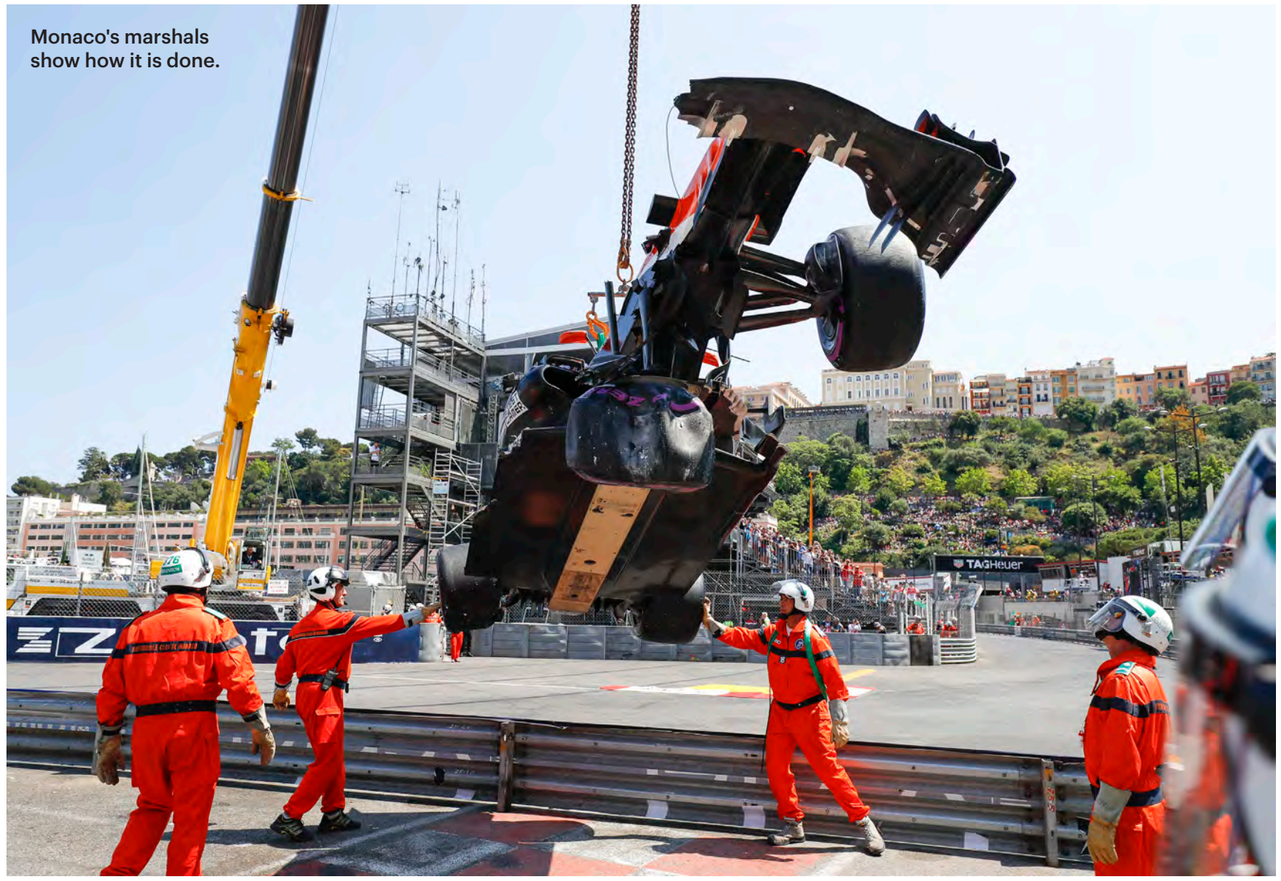
LM: We are working on that right now, so obviously we did do a number of extrication training exercises before the Halo decision was taken, and now it's about finding the best way to deploy that knowledge to as many people as possible. So we have a Halo plan for medical, which is basically how do we bring the medical chain up to speed with the Halo evolutions, and it's something that is very much driven by the FIA Medical Commission.

There will be a dedicated seminar and accreditations that will take place early next year in order to support that. Plus a higher number of training tools such as videos and a large amount of information, which we have made available. We are also producing some dummy halos to be fitted on all our training chassis all over the world so that people can train on people and so on.

A+M: What has been the feedback from CMOs at the circuits?
LM: I think that everybody now is switching to the fact that 'OK, halo is out, so let's make it happen as best as possible', and therefore the response we've had globally is very positive. People want to be ready, they want to be on time, they want to do things properly. So far the response has been very, very good and we've had a lot of inputs and advice from all over the world, so this has been a very positive thing. You have seen also that Formula 3 in America has been launched starting in 2018, and even though the deadline is super tight, these guys are going to go with the Halo as well. So I think there is a turning point now that people are getting on with it and trying to contribute, which is great.

A+M: Do you think that Formula 1 should have a dedicated safety team which goes to each race, similar to NASCAR and IndyCar with the Holmatro team?
LM: It's a very good question. At the FIA we have had both models successfully deployed. In Formula E for example we have a single extrication team going to all events and in F1 we use a circuit-based team model. I think that both schemes have advantages and downsides, but I think we have managed to make both work and there is merit for both of them, so I don't envisage a change short term for that, for Formula 1 or Formula E. In Formula 1 we have a good system, and in Formula E we have a good system.

A+M: How important is regular medical safety training, not just in Formula 1, but in motor sport in general for track teams?
LM: I think it's fundamental. It's like anything we do, practice makes perfect. We are very much training orientated, we like systematic training, that's how we get to the level that we think is required. You know that on top of all the national training that is being done before an event there is systematic training a few days before the event when we arrive at the track with our medical delegates and with the local and national teams to make sure things blend together and are as efficient as possible. We do static training, we do accident simulation training with the dummy car somewhere on the track and sometimes with two cars and sometimes two extrication teams. We do real-life training with an actual F1 team for example, so training is a complete central part of extrication.



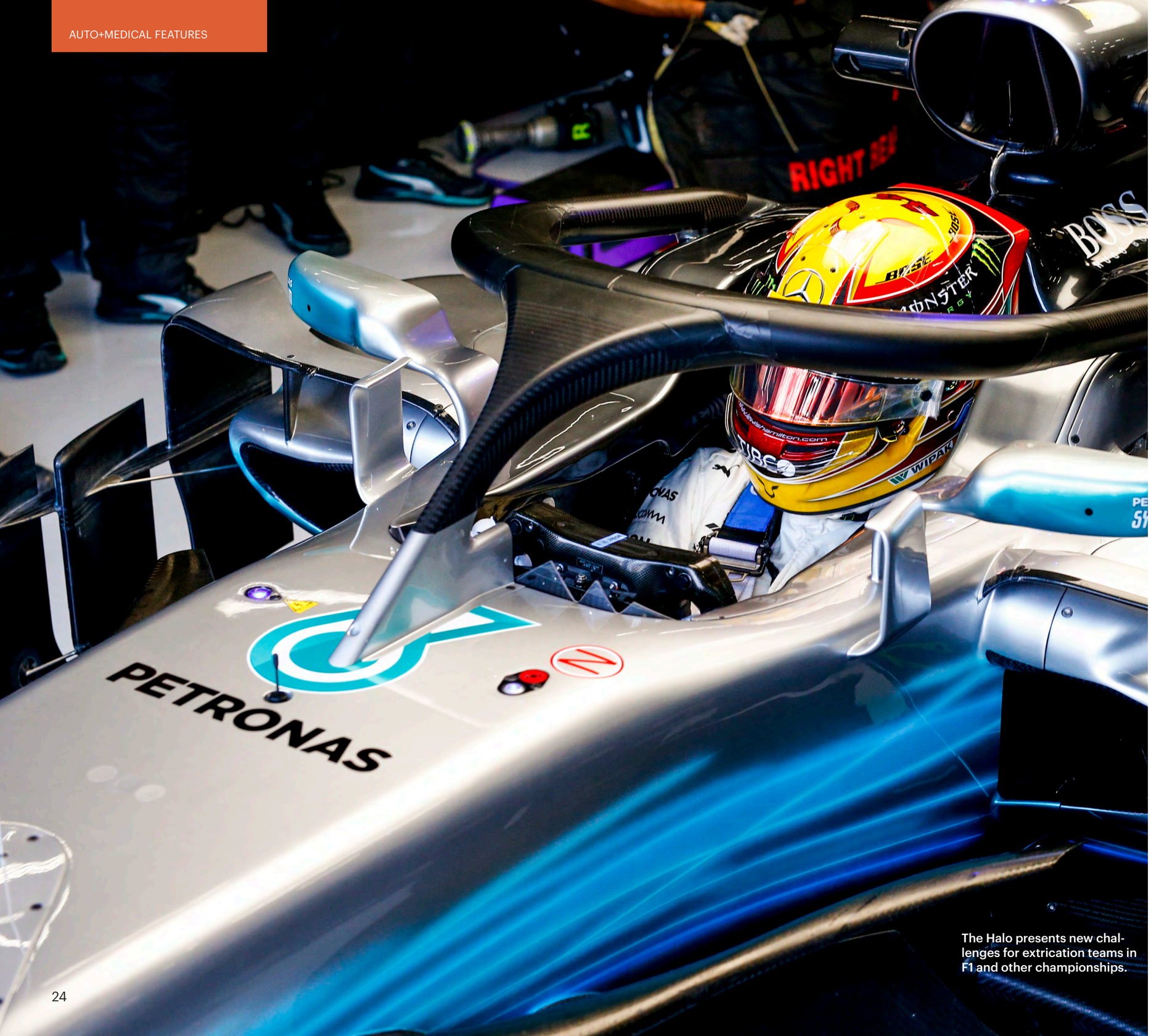
Monaco's marshals show how it is done.


Accident simulations are an essential part of training

> **"EVERYBODY NOW IS THINKING 'HALO IS OUT, LET'S MAKE IT HAPPEN AS BEST AS POSSIBLE' SO THE RESPONSE WE'VE HAD GLOBALLY IS VERY POSITIVE"**

A+M: Finally, what are the other big safety projects that you're focused on this year?
LM: We have 15 live projects, so to mention only a few... Our new biometric gloves will be aiming to take rescue to the next step by giving our people in the medical car early information about the vital signs of the drivers so that we can improve the race recuperations. I think that's one of the big projects for us to deploy that for next year, but we have a lot of requests from other championships so we want to do it properly with one championship next year, with F1, and then if it's successful we anticipate a very large deployment of that as well and further steps to come after that in terms of biometrics, so that's one key one I would say.

Then we have a new helmet standard that's coming for 2019, which will be published sometime in 2018. So we will have a new version of it which is something that we change nearly every ten years, so not every day. We have been working for nearly two years now to bring this product to life with the help of one of the key actors in the industry and that will be one of the highlights of 2018.



The Halo presents new challenges for extrication teams in F1 and other championships.

THE CUTTING EDGE

How motor sport rescue teams stay sharp when it comes to techniques for cutting open the super-strong cars of modern times

For just about any racing series in the world, a car that breaks apart easily is an undesirable one. Higher speeds and better technology mean that today's drivers are always somewhat at risk, but thankfully, with the help of stronger materials and life-preserving survival cells, fragile racing cars are rarely a concern.

These resilient cars are excellent at protecting their occupants and absorbing energy. But while safer and stronger cars help minimise injuries, they can present challenges for rescue and extrication teams at racetracks when they need to get inside and manually extricate an injured racer.

That's why as protective environments for racing drivers evolve, so do the tools and techniques used to pry them open in emergency situations.

"The cutting abilities of the tools have evolved quite dramatically," explains Martin Hunt, Rescue Co-Ordinator for the British Automobile Racing Club (BARC).

"Originally, drivers were removed from cars

Battery-operated tools have largely replaced heavier fuel-powered equipment

by mechanics from their team using standard hand tools – hacksaws, spanners, crowbars and the like, but then things moved on. The UK Motor Sport Association produced a specification for motor sport rescue with help from Derek Ongaro – one of the first Formula One safety advisors – together with Paul Butt, Paddy Kenshole, John Felix and Dr Bob Loynes."

This simple approach with 'low tech' cutting devices did the job when cars were built on ladder chassis and made of sheets of aluminium, but the implementation of monocoques, carbon fibre and stronger metals over the years meant that more complex tools were required.

"As rescue technology moved along, some of the equipment that fire services used started to appear, such as pneumatic air tools and hydraulic tools. By the 70s, most people were using air tools, but they go through air at a terrific rate, so to make sure that you can actually complete a job, you needed two air cylinders.

"Some fire services and rescue units still use air tools, but I think the majority of them are now using battery tools, because they are lighter, more manoeuvrable and spare batteries are easier to store than air cylinders, so we've moved on."

A CUT ABOVE THE REST

Carbon fibre is both a blessing and a curse for rescue teams. Its lightweight, sturdy design is the perfect component for racing cars, but it can be tricky to cut.

"Because it's made with a weave, there are many ways of cutting it," Hunt continued. "It has challenges in that it generates a lot of dust and you have to be careful because it can break into lots of sharp fragments, risking injury to both the casualty and the rescuers.

"You can use hydraulic equipment, reciprocating saws or angle grinders to cut it, and UK rescue units carry an oscillating saw, essentially a plaster saw. Because it oscillates about 5-10 degrees, it won't cut skin or anything soft, but it will cut hard materials. The problem with using these tools to cut carbon fibre is that the blade teeth generate heat as they travel through the material which melts the resin that is used to bond the carbon fibre, so the blades get sticky, and you can't use them anymore. People who manufacture carbon fibre use toothless blades encrusted with industrial diamonds or tungsten carbide."

"PART OF THE SKILL IS UNDERSTANDING THE CONSTRUCTION OF WHAT YOU'RE TRYING TO CUT"

Single seaters are incredibly robust, and take a long time to cut open when necessary

Hunt says that Billy Monger's accident in April, where the 17 year-old driver was trapped in the car, was an eye-opener in terms of just how tough single seaters can be to open when a driver is unable to be simply extricated.

"Until earlier this year when we dealt with the Billy Monger accident at Donington, we hadn't really considered the heat problem, purely because the carbon fibre we have been cutting has been quite thin – seat shells and crash helmets are quite thin – but the outside of a single seater is much thicker, and that generates a lot of heat when you cut it, so in light of that accident we've subsequently found that the best way to cut thick sheets of carbon fibre is to use these diamond encrusted blades. Although in this particular accident we had diamond blades available, the circumstances meant that our option to use them was limited.

"There's certainly some learning there for rescue teams. Using a standard tool on carbon fibre will work, but it's quite slow, and you'll get through a lot of blades."

ROAD RELEVANCE

Motor sport rescue teams are always learning, and what they learn can be applied to everyday motorists. The first carbon fibre monocoque in motor sport was the McLaren MP4/1, in 1981. Some 11 years later, the same manufacturer launched the first such monocoque on the road; the 1992 McLaren F1.

Road cars have always been behind racing cars in this sense, but Hunt says that the knowledge can be passed across.

"Some of the challenges we face in motor sport are only just beginning to impact fire

AUTO+MEDICAL FEATURES

Carbon fibre has long been in motor sport but is set to become prevalent on the road as the lighteweight material of choice for electric cars like the BMW i3.

services. We've long been dealing with carbon fibre cars, whereas road cars are only really just starting to appear in mass production.

"There's some reciprocal learning to do there - we have experience dealing with carbon fibre, and the fire services don't, and carbon fibre has its own challenges if you want to cut it."

In place of synthetic materials, modern road cars are largely outfitted with incredibly strong steel alloys, but these are no less difficult to cut in an extrication scenario.

"Road car manufacturers are under huge pressure to comply with safety standards so they can withstand side and frontal impact tests. From this, a load of ultra-high strength steels have been developed, and cutting them is difficult if you don't have up-to-date hydraulic cutting equipment. You can cut them with saws and angle grinders, but it takes a fair amount of time, it's noisy and it's not pleasant if you're still in the car."

Peter Fiset, regional manager for IndyCar's Holmatro Safety Team, echoes these thoughts, and says that extrication can be hampered when cars are bent heavily out of shape.

"Road vehicles are now made almost the way that race cars are, incorporating tubular strength, so the metals are very hard. The difficulty comes when they bend beyond the design of the vehicle. Then you're dealing with very hard metals that need to be cut, and that delays the rescue time."

Having the correct tool for the job is always beneficial when dealing with an accident, but Hunt says that understanding the design of the car being cut open is even more important.

"Part of the skill of using these tools is understanding the construction of what you're trying to cut up, and how it will behave when you cut it. If you cut the deformed roll cage of a car that's been crushed heavily, it will move. The energy is stored in the bent cage and has to be released, so you need to cut the cage as far away from your casualty as you can, to make sure you've released any energy.

"That's not a situation that fire services encounter. We get some really useful interaction with local fire services in the UK, but their skill is in road cars. Competition cars are prepared differently, because they contain roll cages."

ANGEL ON YOUR SHOULDER

Formula One and its main feeder series, Formula Two, are set to introduce the Halo head protection system for their respective 2018 seasons, increasing frontal protection from debris, but maintaining the open-cockpit nature of single seaters.

And while this titanium structure has been rigorously tested in regards to deflection tests and driver visibility, the challenge of manually extracting a driver, or indeed cutting away a section, has only recently been explored.

"We did an initial cutting exercise with Holmatro at Brands Hatch," says Hunt. "The Halo behaves much how you would expect high-strength steel to behave when you cut it – it fails very suddenly rather than compressing and then cutting."

The Halo sits just inches away from a driver's face, meaning that if partial removal of the device is necessary – perhaps after deformation occurs from being struck by debris – tools must be used with the utmost precision.

"You would be cutting close to somebody's head and shoulders, so there's a lot of care required," Hunt continued. "You don't have the luxury in that environment of cutting a long way away from the patient to release any stored energy, so there needs to be an awareness that there's a big potential for the sudden release of trapped energy when it fails. There needs to be an awareness of what the implications of doing that so close to someone's head are."

Much in the same way that stronger modern cars present obstacles with cutting pillars and materials, the fact that the Halo will be fixed to cars and non-detachable means that it may need to be dismantled before extraction can take place, as Fiset explains.

"After certain accidents, we don't know what the deformation is going to be. For instance, it might be in the way of moving the seat of the car in a standard driver extraction. We've been invited to help the FIA with a solution to cut that if they have to remove it in a hurry.

"If we have a driver still in the seat unconscious and with airway issues, that's where we're going to have the biggest concern about the Halo being in the way. Getting to the driver's airway needs to take absolute priority, and is going to be one of the initial challenges."

The height of the device could also prove to be a very literal barrier. Though there is no physical wall on the side of the Halo, it effectively adds several inches to the outer edge of the cockpit, which could complicate rescue efforts in some cases, says Fiset.

"Another challenge with the Halo is the added reach-down into the car, and this could be a challenge for some rescue packs. I'm not a terribly tall guy, but I have some tall colleagues, so their arm reach is going to be better than mine."

However, Fiset says that the potential life-saving qualities far outweigh any negatives associated with longer extraction times.

"Every time someone complains about a safety feature, I always look at the bright side. If we're able to extract a healthy driver who is less injured and stands a chance of being back in the car in a few weeks, I think that's just fantastic."

INSIDE THE MEDICAL CENTRE FOR THE FRENCH GRAND PRIX

AUTO+ Medical takes a look at the medical equipment, facilities and operations at Circuit Paul Ricard, as it prepares for the first French Grand Prix in ten years.

AUTO+MEDICAL FEATURES

In 2018, the FIA Formula One World Championship will host its first French Grand Prix in a decade, at the Circuit Paul Ricard in le Castellet, near Marseille. Though the circuit plays host to regular track days, national-level competitions and occasional tyre tests, the challenges of providing medical assistance and intervention for a World Championship event are another matter.

The circuit's permanent Medical Centre is under the direction of Chief Medical Officer Dr Jean-Francois Amoros, and he expects an increase in staffing of 50-70 per cent over the three-day event, to ensure the medical demands of hosting a World Championship event are met. He works together with a staff of medical professionals and a team of firemen, who are all on permanent alert whenever the circuit is open.

The Medical Centre has its own Video Control Room, equipped with four screens, which allow immediate dispatch of the appropriate assistance.

The FIA carried out homologation of the circuit's facilities in October, confirming that the facilities were up to standard. Two sets of medical staff will be on alert during the Grand Prix; one for the track, and one dedicated to the public with extra doctors, nurses and first aiders.

Dr Amoros talks to AUTO+ Medical about the latest facilities and equipment at the circuit.

Dr Jean-Francois Amoros has been the Chief Medical Officer at Circuit Paul Ricard for the last ten years, and works with a medical team comprised of 18 doctors and 12 nurses..

THE FACILITIES
The circuit is well-equipped to deal with medical emergencies. As well as the pictured intensive care unit, Circuit Paul Ricard also has a major trauma facility with two medical beds, a radiography facility, a bathtub for burn victims, an examination room for small injuries, and a recuperation room with two beds.

EMERGENCY VEHICLES
The Circuit is equipped with a fleet of emergency vehicles for global events, including two ambulances, two medical cars, two extraction cars and two extrication vehicles. Additionally, an intensive care ambulance (pictured) is at the disposal of the medical team, and is located between the pit lane and the helicopter drop zone.

VIDEO CONTROL ROOM
The Medical Centre team is in constant communication with the track manager, based in the circuit's Video Control Room. They communicate via a dedicated emergency telephone line codenamed 'The red telephone', pictured left.

All photos courtesy of Morgan Mathurin

BURN VICTIMS
Situated within the Intensive Care Unit, this "bath tub" is used to treat any patients who have suffered burns in an accident.

THE ROAD BACK:

SEBASTIEN BOURDAIS

The IndyCar racer and four-time Champ Car series champion discusses his remarkable recovery from a 230 miles per hour crash at the 2017 Indy 500

INTERVIEW: JAMES NEWBOLD/ AUTOSPORT

During Qualifying for the 2017 Indy 500, Sébastien Bourdais lost control of the rear end of his car at 230 miles per hour in the middle of Turn 2. He counter-steered to catch the slide, but the front tyres suddenly gripped, and he hit the outer wall at a near 45-degree angle. The resulting impact meant he sustained a shattered pelvis, fractured right hip, and two broken ribs, but amazingly, he overcame these injuries in just eight weeks to attend a mid-season test, before making a full racing return in the final three rounds of the 2017 IndyCar season. He spoke to AUTO+ Medical about his injuries and swift recovery.

AUTO+ Medical: You haven't had many big crashes in your career, so was this even more of a shock?
Sébastien Bourdais: I've never hurt myself physically before. I've had some sizeable shunts before, but none where I ended up at the hospital with an inactivity period, so it was all very new to me.

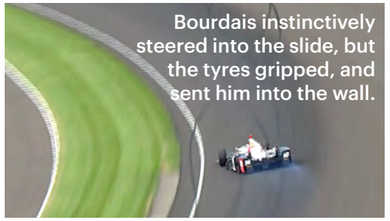
A+M: You remained conscious despite the 118G impact - would it have been better to be knocked out?
SB: I think there are some plusses and minuses about staying conscious or being knocked out, but I don't have a strong opinion about that. I kind of wish I had been knocked out because at least then I wouldn't have been in so much pain.

A+M: What was your thought process after the accident?
SB: There's always the scary period post-crash when everybody is trying to work out how bad it is. Once I got the bigger picture - that things were broken but nothing that couldn't be fixed within a reasonable amount of time - I wasn't too worried. There is the crash at the beginning, then the pain, and then you get the analysis and think, it's not going to be pleasant, but we'll make it through.

We talked about how things were going to work out with orthopaedic surgeon Dr Kevin Scheid after he did the surgery, the Sunday after the crash. The timeframe was about six weeks for weight bearing, eight weeks for walking and feeling normal, and then three months to get back in the car. At that point, it was clear to me that the objective was to get back in the car for the last race, and if I was going to be ready for the last race then I was going to be ready for Watkins Glen, two

Bourdais returned to action just eight weeks after sustaining a shattered pelvis, fractured hip and broken ribs

AUTO+MEDICAL FEATURES



weeks earlier.

Providing everything went to plan, there was no reason to sit out the rest of the season. I think doctors are always very cautious with their prognosis, so I guess they told me I was out for the season to take the pressure off me. The bone healed pretty well, I don't have much point of comparison because I haven't broken anything before. I had no idea how fast it would heal but it turned out that my body recovers pretty well.

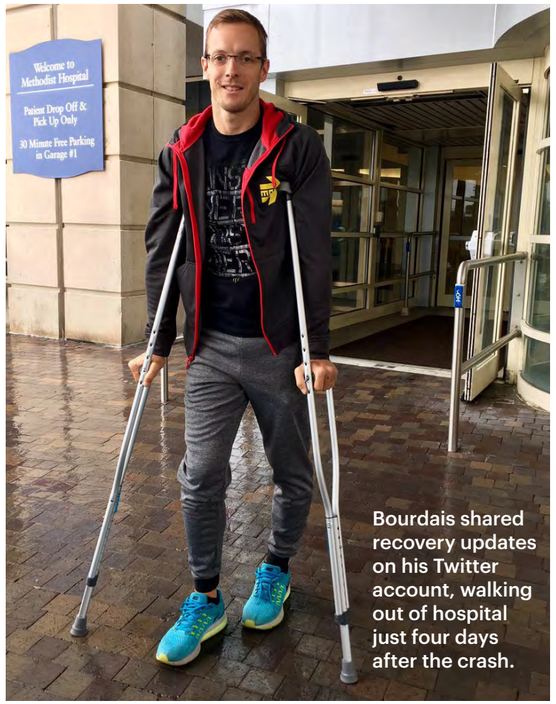
A+M: What did your physiotherapy consist of, and how did you deal with the injuries?
SB: I had broken ribs, so crutches were not exactly the best thing for mobility. From the offset I thought about what the smartest and best way to deal with the injury was going to be. My wife hated me using a wheelchair, but it was a 15-minute crutches walk, or three minutes in the wheelchair to get to the rehab place, and I was going three times a day. It wasn't very pleasant, but you've got to be practical at that time.

A+M: Due to your fitness level, doctors operated on both your hip and pelvis simultaneously - did that speed up recovery?
SB: They all said I have a really fast metabolism, which tends to accelerate the healing process, but I wouldn't venture trying to explain that. Everybody has got their own rate of reconstructing their bones and soft tissue injuries, so you're never quite sure how fast things like that are going to recover. I recovered fairly well and although there are better days than others, it all turned out okay."

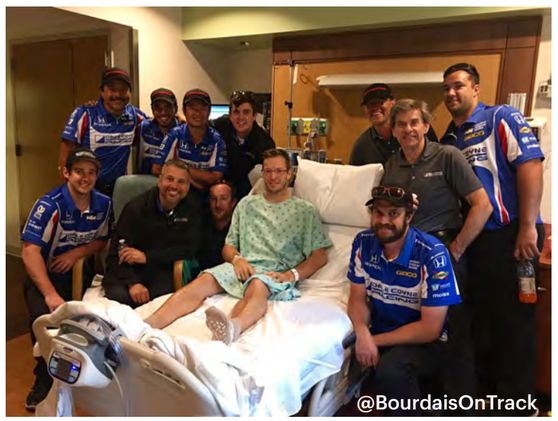
A+M: How does it make you feel to have beaten the projected timeframe for recovery?
SB: I tried to follow instructions as best as I could, because the last thing I wanted to do was rush things and make it worse, especially at the very beginning when dealing with bone reconstruction. I tried to be mindful and listen to what they told me because I always had in mind that a return was possible, and we talked about it. It wasn't a case of me just saying 'I'm going to do the last race.'

I started thinking and talking about coming back before the end of the season when I had been prescribed a timeframe of what was going to be allowed, providing certain criteria were filled. I didn't do what the Moto GP guys do, who just ride with broken bones and take their chances. They know that if they crash with pins and plates in they could break them, and then they're going to need more surgery,

"I KIND OF WISH I HAD BEEN KNOCKED OUT BECAUSE THEN I WOULDN'T HAVE BEEN IN SO MUCH PAIN."



Bourdais shared recovery updates on his Twitter account, walking out of hospital just four days after the crash.



which might not be that easy to fix. For us, thankfully, we crash, but we don't get hurt every time.

I certainly wasn't going to go against the doctors and say, "I don't care, I'm getting back in the car" because with that same mindset I could have done the Indy 500. Physically if you're willing to accept taking the chance, it's possible, but if I had any kind of crash then I was right back where I was, and in worse shape. The big concern with the femur neck is it's a tricky bone, there's only one irrigation point and if you sever that, then you're going to need an artificial hip, because the bone is screwed.

In the old days, you would have been in a hospital for a month with the injuries that I had - I was out of the hospital after four days. Putting everything in perspective, I've tried to be cautious, but once I got the green light and everything was strong enough to take another hit, there was no reason to hold back and sit out the rest of the season.

A+M: How satisfying was your comeback test at Mid-Ohio? Was there ever a worry that you might not perform at the same level as you did before the crash?
SB: Inside the car I really don't feel much of anything as far as the hip is concerned. At the Mid-Ohio test in July, the biggest problem was the neck. I must have pulled a muscle, so I couldn't quite drive without padding, but other than that it was all pretty good. It was just a

matter of doing laps, feeling comfortable, and regaining confidence. The test went well enough that when I got the all-clear to get back to racing two weeks later, I didn't think twice about it.

It was only three months out of the car, and we have longer off-seasons than that! What makes it challenging is the long inactivity period, because you lose muscle twice as fast when you are mostly sitting or lying down for the first two months. That was definitely a time to work pretty hard at it to physically get back.

"ONCE I GOT THE GREEN LIGHT, THERE WAS NO REASON TO HOLD BACK AND SIT OUT THE REST OF THE SEASON"

A+M: Would it have been harder next season if you didn't return before the end of 2017?

SB: For me, it was very much about giving myself every chance of being successful next year. When we come back in St. Petersburg next year, all I want to talk about is the season ahead, not how I managed to come back and where I'm at physically. For me, it's important that this chapter is closed, and that we're focusing on the job ahead instead of unpleasant memories. That was only going to happen if people saw me as they used to see me and not as a guy who has survived something and is just coming back. I completely understand, but I just wanted to get ahead of it and put it behind me.

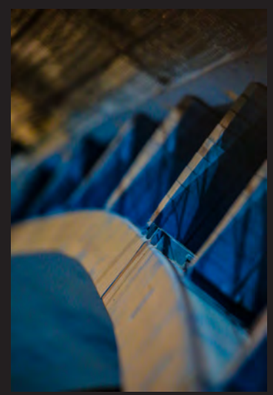
Bourdais started the 2017 season in fine form, winning the opening race at St. Petersburg.

THE SAFER BARRIER

Bourdais believes that he would have died if not for the massive advancements in motor sport safety over the last few decades. One of the most prominent introductions, certainly in American oval racing, has been that of the Steel and Foam Energy Reduction (SAFER) barrier. Though French driver's injuries were severe, this energy-absorbing structure helped reduce the massive 118G impact at Indianapolis. This, combined with the deliberate deformation of the car's crash structures and the swift intervention of the Holmatro Safety Team all contributed to his ability to walk out of hospital just four days after the crash.

Many have likened the crash to the fatal accident of Gordon Smiley, who was killed in a crash at Turn 3 during Qualifying for the 1982 Indy 500. Much like Bourdais, he steered into a slide when the rear of the car oversteered, but the front tyres gripped, and he too was sent into the wall. The car disintegrated, sending wheels, the engine, the flaming fuel tank, and Smiley himself flying across the track. Though the accident was a tragic loss, Bourdais' survival 35 years later, and incredible recovery, is a testament to just how far safety has progressed.


Steel and Foam barriers absorb energy on the fast banked corners at most oval tracks.



SCIENCE

CONCUSSION IN MOTOR SPORT: A MEDICAL LITERATURE REVIEW AND ENGINEERING PERSPECTIVE

‘WARNING: motor sport can be dangerous’. The spectrum of head injuries in motor sport has shifted dramatically in recent decades, fuelled by advances in medicine and engineering. Despite these successes, there are growing public and professional concerns regarding concussion in motor sport. This review appraises the published literature concerning concussion in motor sport, with particular focus on the current medical and technical challenges in the field. The incidence and assessment of concussion in motor sport is discussed, in addition to modifiable risk factors within and outside the automobile environment. Lastly, areas for further research and development are outlined.

Authors: Naomi D Deakin, Thomas Cronin, Paul Trafford, Stephen Olvey, Ian Roberts, Andrew Mellor, Peter J Hutchinson

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AUTO+MEDICAL SCIENCE

Impact data suggests that nearly 10 per cent of a select group of NASCAR collisions between 2002 and 2008 resulted in a mild concussion.

INTRODUCTION

Motor sport spans a diverse range of events worldwide, encompassing recreational, amateur and professional competition across a broad range of two- and four-wheeled vehicles. These automobiles range from the historic to the state-of-the-art; designed for the road, circuit, all-terrain and rally; engineered to withstand desert heat or sub-zero temperatures of the Arctic. This vast array of vehicles is united by competition and regulated by numerous governing bodies worldwide, each of whom have differing guidelines and recommendations for the assessment and management of the rider or driver diagnosed with head injury.

The spectrum of head injury in motor sport is changing, presenting new challenges to staff both trackside and in onward medical referral centres. The incidence of severe traumatic brain injury has significantly decreased over the past decades, thanks to progress made in the fields of both engineering and medicine. There appears to have been a graduated shift away from severe brain injury and towards mild traumatic brain injury (mTBI) and concussion. This shift has contributed to reduced mortality in motor sport, yet significant morbidity remains.

The Concussion in Sport Group (CISG), a panel of experts in sports concussion first established in 2001 and led initially by representatives from ice hockey, football and the Olympic Medical Commission, define concussion as: 'a complex pathophysiological process affecting the brain induced by biomechanical forces'. Concussion is largely a clinical diagnosis, classified by some as a subset of mTBI, which encompasses a heterogenous spectrum of disease and is usually self-limiting. However accurate, objective diagnosis of concussion remains problematic in motor sport. Additionally, there are now concerns regarding long-term negative neurobehavioural outcomes following this diagnosis in other sports.

Driver safety in motor sport is paramount, and mitigating concussion is no exception. Recent advances in protective equipment, for the competitor or their racing environment, have an important role to play in the reduction of concussion. Furthermore, when incidents do occur, it is now possible to analyse the causative forces in an effort to prevent similar injury to future participants.

Lastly, in contrast to other high-risk sports where the effects of concussion are typically limited to the individual, competitors returning to motor sport remain in control of a high-speed vehicle that poses a threat to themselves, other competitors and spectators. Unsurprisingly therefore, the return to race decision in motor sport is of vital importance and must be carefully conducted by all professionals involved.

This review seeks to outline the current medical and technical challenges of concussion in motor sport. Information is extracted largely from published sources and supplemented by the authors' own data. The incidence and assessment of concussion in motor sport will be discussed, in addition to modifiable risk factors both within and outside the automobile environment. Lastly, promising areas for further research in the fields of medicine and engineering are outlined.

METHOD

A MEDLINE search strategy was developed and adapted for use in PubMed, TRIP and Cochrane. Scoping searches refined the terms and ensured that relevant studies were obtained. The initial search was complete on 18 October 2016 and was updated in January 2017. No date limits were applied and studies were limited to the English language.

Search terms related to concussion included head injury, mTBI and neurotrauma; for motor sport the terms chosen aimed to create as broad a search as possible across amateur and professional racing and throughout the classes (see Appendix 1). The initial search yielded 4575 studies which were reviewed using title and abstract. Exclusion criteria included all non-human studies. Secondary searches of bibliographies added further publications which were assessed with the criteria outlined above. A small number of additional publications were added by the authors, who had access to historic and offline papers.

A qualitative review of 127 full publications was conducted by two independent reviewers; all disputes were resolved. Only those studies influential in the field or adding new knowledge to the existing literature are discussed in this review.

Four-time IndyCar champion Dario Franchitti retired from racing after doctors warned he may suffer permanent paralysis if he had another concussion.

RESULTS

The problem of concussion in motor sport

With adjustment for national sports participation figures, 'motor sport' was attributed the highest rate of concussion (181 per 100,000 participants; 0.18%) in a nine-year retrospective study from Victoria, Australia.[1] This retrospective analysis identified 4745 hospital attendances for

sports-related concussion, with motor sport as the cause in 14% (n = 674); third behind Australian football and cycling. The nature of participation was not defined. However, analysis of all types of motor racing at a single circuit in the United Kingdom found that 23 of 364 competitors were diagnosed with minor head injury over a five-year period, representing a far lower prevalence of 6.3%.[2] Additional estimates of prevalence across recreational and competitive motor sport are outlined in Table 1, in addition to calculation of an annual rate.

A relatively large portion of the motor sport literature explores concussion in motocross events. A retrospective study conducted at a single US trauma centre analysed injuries attributable to a nearby annual motocross competition; 51 competitors from four annual competitions attended the facility, with 16% (n = 8) diagnosed with concussion during the study period.[4] A similar analysis of emergency department attendances at a single centre in the United States found that 9.5% (n = 56) of all treated injuries were concussion in motocross and all-terrain vehicle riders.[5] In a separate study, when surveying an entire motocross racing season, it was found that 48% (n = 67) of riders experienced at least one self-reported symptom of concussion.[12] These results were translated to Emergency Department attendances in a separate study at the same institution, where it was found that between 2000 and 2007, 19% (n = 57) of all attendances were attributed to concussion. Finally, providing a national overview for the United States, an 11-year retrospective study using the National Electronic Injury Surveillance System database recorded concussion as the most common form of head and neck injury in motocross (although participant level was not defined), accounting for 29% (n = 22,788) of these injuries.[13] In summary, concussion in motocross is highlighted as one of the most common injuries sustained, with presentations ranging from 9.5% to 19% in competitive events.

Table 1. Overview of concussion diagnoses in motor sport from the published literature: proportion of diagnoses and annual rate of concussion.

Type of motor sport	Study title	Percentage of concussed patients (total number)	Total number of patients	Study duration (years)	Annual rate of concussion (percentage of concussed patients per study year)[a]
Not defined	Increasing the incidence of hospitalisation for sports-related concussion in Victoria, Australia[1]	**14.2%**[b] (n = 674)	4745	**9**	**1.58**
	What are the requirements for medical cover at motor racing circuits?[2]	**6.3%** (n = 23)	364	**5**	**1.26**
Motocross	Concussion symptoms in youth motocross riders: a prospective, observational study[3]	**19.1%** (n = 57)	298	**7**	**2.73**
	Pediatric injuries at an annual motocross competition: rates and severity[4]	**15.7%** (n = 8)	51	**4**	**3.92**
	A comparison of injuries sustained from recreational compared to organized motorized vehicle use in children[5] (and ATVs)	**9.5%** (n = 56)	589	**6**	**1.58**
Professional 4-wheeled	Injuries in professional motor car racing drivers at a racing circuit between 1996 and 2000[6] (**saloon, single-seaters**)	**2.7%** (n = 3)	112	**4**	**0.67**
	Development of head injury assessment reference values based on NASA injury modeling[7] (**NASCAR**)	**9.9%** (n = 27)	274	**6**	**1.64**
	Physical demands, injuries and conditioning practices of stock car drivers[8]	**22.5%** (n = 9)	40	**Career**	Not calculable[c]
Professional; 2-wheeled	Elite motorcycle racing: crash types and injury patterns in the MotoGP class[9] (**MotoGP**)	**20%** (n = 2)	10	**3 of 18 events** (one season)	Not calculable[d]
	Epidemiology of injuries in the 2014 MotoGP World Championship: The 'Clinica Mobile' experience[10] (**MotoGP**)	**1.6%** (n = 3)	191	**1**	**1.57**
	Sports injury or trauma? Injuries of the competition off-road motorcyclist[11] (**Enduro**)	**7.4%** (n = 9)	121	**4**	**1.86**

Rates of concussion in professional motor sport

Disappointingly, much less data have been published for professional motor sport racing. The earliest published study of professional four-wheel racing is from Indy Racing League (IRL), where a survey of 124 drivers during four racing seasons (1981–1984) found that only 13 drivers reported previous head injury (defined as loss of consciousness (LOC), with admission for observation or treatment), a prevalence of 10.5%. Throughout the study period, IRL and Championship Auto Racing Teams (CART) had comparable rates of head injury at 16.6% and 17.6%, respectively. Of note, all competitors returned to competitive driving.[14] In contrast, figures from 12 years later (1996–2000) give an incidence of 1.2 concussions per 1000 drives. This data is from a single-centre four-year retrospective study at the Fuji Speedway which investigated all injuries presented to the circuit medical centre, encompassing professional saloon car and single seat racing. Concussion was defined as any driver with amnesia or confusion and diagnosed in 3 out of 112 drivers (2.7%).[6] The most recent study, a retrospective analysis of all National Association for Stock Car Auto Racing (NASCAR) impact data from the 2002–2008 race seasons, found that head injury (mild concussion, with or without LOC) occurred in 27 of the 274 selected impacts (9.9%). These data are difficult to interpret, but are the only published information for this racing series.[7] In contrast, unpublished data from the British Touring Car Championship (BTCC) and its support series illustrate that the incidence of concussion may be increasing. Formal diagnoses from the Race Medical Director numbered zero to one annually in the early 1990s and are now in double figures. Data from the most recent seasons are as follows: 6 (2012), 7 (2013), 8 (2014), 11 (2015) and 6 (2016). At the time of writing, one diagnosis of concussion has already been made during pre-season testing in the British Formula 4

AUTO+MEDICAL SCIENCE

Championship (certified by the Fédération Internationale de l'Automobile (FIA) and powered by Ford).

A small body of literature relates specifically to professional two-wheel competition, extracted from exhaustive MotoGP data. A study of three US MotoGP races in 2013 (including practice sessions, qualifying and race) recorded 78 crashes, with an incidence rate of 9.7 crashes per 100 rider hours. Ten riders attended the medical facility, with two diagnosed with concussion, resulting in a disproportionately high proportion of concussion diagnoses (20%).[9] A far smaller proportion of concussion diagnoses was collected from the internal database of the 'Clinica Mobile' medical team during the 2014 season, encompassing MotoGP, Moto2 and Moto3. Injury was defined as the 'inability to race or train', and of the 191 recorded, 1.6% (n = 3) were concussion.[10]

Concussion in the adolescent

Regardless of amateur or professional racing status, there is a growing number of adolescent participants in motor sport. Analysis by this sub-type is largely under-represented in the literature; however, a single study provides data for adolescent motocross riders during the 2000–2007 seasons. A total of 299 injuries were recorded in 249 patients, of which head trauma with LOC was reported in 18% of cases. There was an average of 1.37 concussive episodes during the study period (range one to five), and 33% of riders reported repetitive head injuries during the seven-year study period.[3]

Assessment and identification

Key clinical features of concussion include confusion and memory loss of varying degrees and duration. Historically, definitions

"GOVERNING BODIES HAVE DIFFERING GUIDELINES AND RECOMMENDATIONS FOR THE ASSESSMENT AND MANAGEMENT OF HEAD INJURIES"

have also included LOC; however, this is no longer a diagnostic criterion. Indeed, recently published literature highlights that LOC occurs in less than 10% of sports-related concussion. The lack of clear clinical diagnostic criteria and objective diagnostic tools results in real challenges for those providing medical cover for motor sport events.

Diagnosing concussion in motor sport

The poor specificity of concussive symptoms was highlighted in the published literature by Luo et al.,[11] who found that a large proportion of competitors continued to display symptoms of concussion throughout the racing season.[12] Similarly, Colburn and Meyer concluded that concussion figures were likely to be under-documented, despite representing the most common non-orthopaedic injury identified in their cross-sectional study.[11] The same study also examined self-reporting of concussion in motor sport, one of only two publications to do so. A questionnaire was utilised to report on the types of injuries sustained during four international six-day Enduro events. Of the 172 drivers, 121 were injured during the study period and only 7% (n = 9) reported concussion. Self-reporting was further analysed by a mixed methods questionnaire study of 40 American professional stock car racers who reported on the diagnosis of concussion throughout their careers.[8] A quarter of drivers (n = 10) admitted to concussion during their racing lifetime. Concussion and head injury were the second most common injury-related fear amongst the surveyed participants.

Diagnosis trackside

Only one motor sport governing body publicly mandates the diagnostic tool utilised for concussion trackside. The Federation Internationale de Motocyclisme (FIM) states that: "in the event of a suspected concussion, the rider should be assessed using a recognised assessment tool such as SCAT3 (Sports Concussion Assessment Tool) or similar".[15] Of note, SCAT3 includes a neck examination and additional symptoms which are not included in the previous version, SCAT2. Internal guidelines for Indy Car advise the use of SCAT3 at on-site medical facilities. Colloquial sources also suggest that the King-Devick is utilised, but this is not corroborated in published literature or available guidelines.

Fernando Alonso missed the first race of the 2015 F1 season after being concussed in a testing crash.

Computerised neurocognitive tests

There has been a wave of computerised neurocognitive tests (CNTs) in the past decade, which aim to objectify the diagnosis of concussion. More recently, these platforms have become internet-based, and all have standardised and often automated scoring systems. These ready-prepared tools are employed across a huge range of sports internationally and implemented by a variety of medical personnel.

The Immediate Post Concussion Assessment and Cognitive Testing tool (ImPACT) was created in the 1990s and employed by many professional American sports associations, including the National Football League, National Hockey League and Major League Baseball since its inception. This CNT is performed in 45 minutes and produces four composite scores: verbal memory, visual memory, visual-motor processing speed and reaction time.

A formal review of ImPACT in sport highlights that the validity and utility of this CNT is strongly affected by environmental, administrator and participant factors.[16] Extrinsic factors include the suitability of the testing environment and the clarity and reproducibility of administrator instructions. Participant factors included physical exertion and hours of sleep prior to testing. The same review highlights that 10%–35% of athletes could intentionally under-perform in their baseline assessment, thus invalidating their post-injury measures. In a separate publication, the authors stated that these threats to validity could be addressed by rigorous standards of clinical practice.[17] Further exploration of measurement error for ImPACT in the systematic review found that 22%–46% of participants experienced a

The Head and Neck Support (HANS) device was introduced in CART in 2002, before being made mandatory by the FIA in 2003.

change that exceeded the measurement error in at least one ImPACT composite score; representing an unreliable change.[16] This review questioned the diagnostic accuracy of ImPACT, owing to the poor to moderate reliability of most scores. Indeed, it was specifically stated that: "it is hard to establish the diagnosis of concussion on the basis of ImPACT testing alone".[16]

To date, there have been no publications which specifically analyse the use of ImPACT in motor sport, yet ImPACT has been utilised without specific validation in this field since the early 2000s, in the absence of an alternative CNT. ImPACT was first mandated by CART in 2002, later by NASCAR in 2014 and currently mandated by FIA for Formula 1 and other selected international series. Use of ImPACT is also advised by the FIM, AMA ProRacing and the CNT of choice for Indy Car.

PROTECTIVE MEASURES TO MINIMISE CONCUSSION IN MOTOR SPORT

Competitor protective equipment: helmets, HANS and headrests

The theoretical utility of helmets in preventing concussion is stated as two-fold in a review by Barth et al.[18]; firstly, "the cushioning effect of helmets increases the distance of deceleration and reduces the forces associated" and, secondly, on a more basic physical level, the use of helmets increases the surface area across which the blow or force is absorbed. Regardless, it is

acknowledged that changes in driver velocity greatly influence clinical outcome. In contrast, a more in-depth review by Lloyd and Conidi collates data from biomechanists and sports neurologists, concluding that helmets do not produce significant protection against concussion, although severe brain injury (such as subdural haematoma) was the main exploratory aim.[19] Finally, a single study was identified which specifically commented upon helmet use and concussive symptoms in motor sport. Prospective analysis of motocross riders at a regional racetrack during the 2010 season found that professional helmet fitting was associated with a 41% decrease in the development of concussive symptoms. The use of neck braces was found not to correlate significantly with a reduction.[3]

The Head and Neck Support device (HANS) was first introduced by CART in 2002 and mandated by the FIA in 2003. The HANS was designed with the aim to reduce fatal cranio-vertebral dissociation injuries by transferring the weight of the helmet and head impact loads to the shoulder belts. HANS prototypes were tested using track, sled and direct impact tests in an initial biomechanical feasibility study, which also implied a theoretical reduction in head injury.[20] This ideology is supported by data from a single study of the CART racing series, published in 2002.[21]

> **“HANS WAS DESIGNED TO REDUCE FATAL INJURIES BY TRANSFERRING THE WEIGHT OF THE HELMET AND HEAD IMPACT TO THE SHOULDERS”**

In direct response to a dramatic rise in severe head injuries in the IRL during the 1997 season (n = 7), the race medical team personnel collaborated with engineering colleagues to alter the composition and location of the in-car padding. This change not only reduced severe head injuries but also minimised the incidence of concussion. This positive affect persisted throughout the 1998 and 1999 seasons.[22] Other attempts at modifying in-car protective measures in order to minimise concussion have included safety harnesses[23] and airbags; the former successful and the latter not.[24]

Altering the competitive environment

There is a large amount of literature which investigates the magnitude of a single impact sufficient to cause brain injury; however, few studies specifically comment upon concussion. Furthermore, the varied nature of motor sport incidents (their speed, direction and magnitude) provides a unique platform for analysis of the causative forces implicated in concussion.

The relationship between vehicle gravitational (g) forces sustained at impact and subsequent brain injury was examined during IRL car crashes from 1996 to 2003. For the purpose of analysis, the impacts were separated into those sustaining either <50 g or >50 g. Almost a fifth of those drivers sustaining an impact >50 g were diagnosed with a head injury (16.0%, n = 30), compared to 1.6% (n = 3) in those of <50 g ($P < 0.001$). The mean peak g for those with head injury was 79.6 g (SD = 28.5) versus 50.6 g (SD = 28.0) in those with no head injury ($P < 0.001$).[25] Additional impact metrics associated with head injury were explored during the 2002–2008 NASCAR seasons. National Aeronautics

and Space Administration (NASA) injury-modelling techniques were utilised to re-create the recorded crashes (n = 274), of which 27 resulted in head injury (defined as mild concussions, with or without LOC). Four metrics correlated well with subsequent head injury: head resultant acceleration, head change in velocity and head injury criterion (HIC) 15 and 36.[7] Furthermore, in reconstructive analysis of a single motocross accident, peak change in rotational velocity and HIC correlated with maximal principal strain on the brain. The authors concluded that rotational kinematics contributed insignificantly to the pressure response (which in turn correlates with brain injury).[26] Finally, the type of impact most likely to result in LOC was highlighted by analysis of NASCAR crashes over a three-year period, identifying lateral motion as the causative factor. Unfortunately, however, concussion was not specifically mentioned.[27] This final notion is supported by analysis of the neuromuscular capabilities of professional racing drivers, where it was found that open-wheel competition resulted in stronger lateral neck flexion musculature.[28]

RETURNING TO RACE: CURRENT GUIDELINES IN MOTOR SPORT

A recent survey published in the FIA medical journal, AUTO+ Medical, found that 70% of competitors: "did not feel completely normal" when they attempted to return to race.[29] There are no formally published studies examining return to race decisions in motor sport after concussion, and therefore, this process must be guided largely by data published for road driving and other sports.

Road driving after concussion

For those road drivers with severe concussion, it has been shown that both task and driving performance are reduced after injury.[30] Furthermore, objective studies have also shown that traffic hazard perception is impaired in the short-term following concussion;[31] however, this is not replicated in the long-term after self-reported diagnoses.[32] A small quasi-experimental case–control study examining road driving has also shown that patients with mTBI should not drive for 24 hours; however, the optimum period for abstinence was not explored.[33]

Recommendations for other sports

The most influential guidelines for the management of concussion in sport are produced by the CISG, who first met in Vienna in 2001, where a consensus definition for sports-related concussion was produced. Minor revisions were made in Prague in 2004 and Zurich in 2008. During the most recently published meeting of the CISG (Zurich, 2012), concussion was formally defined as: "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces".[34] Five major features were defined relating to the causative event, resultant symptomatology and absence of radiological changes. Additionally, same-day return to play was eliminated for any athlete for which there is a suspicion of concussion. Outside of these guidelines, the general clinical consensus is that athletes should be asymptomatic and cognitively unimpaired before a return to play (or race). For contact sports, the recovery time from sports-related concussion is estimated as 5–10 days after injury.

Table 2. The first MSA concussion guidelines, published in the annual update of the Yearbook, on 1 March 2016.36

A11. Concussive injury can be serious, especially if repeated within a short period or in the younger age group. For this reason, the MSA has introduced this policy restricting activity following this type of injury. Concussion is diagnosed following an accident including the following symptoms: • Transient unconsciousness (not always present) • Confusion/disorientation • Amnesia • Headache • Dizziness/nausea Following diagnosis of one or more of these symptoms, this policy must be instituted by the meeting/event Chief Medical Officer or equivalent.
A11.1. The competitor must not compete further in the meeting/event (including subsequent days).
A11.2. The competitor's licence should be suspended and retained by the Clerk of the Course, then forwarded to the Medical Department of the MSA, together with a note explaining the reason for return.
A11.3. Upon receiving the licence, the MSA will send the licence holder an explanatory letter with a pro forma for them to take to their GP or licence medical issuing doctor. This will ask the doctor to confirm the absence of symptoms.
A11.4. Upon receipt of the pro forma, certifying the absence of symptoms, the licence will be returned. Any concerns should be notified to the Chairman of the Medical Advisory Panel.
A11.5. It is important that the competitor is advised not to drive any vehicle until symptoms have resolved. They should also be advised to consider discussing their employment role with either their Occupational Health Department or General Practitioner.
A11.6. Professional racing series, where regular medical personnel attend, may institute their own policy, provided this policy is followed as a minimum.
A11.7. The duration of symptoms is variable, with most cases recovering within a period of two to three weeks. This policy should generally cover that period. Some cases have persistent symptoms, in these cases, expert opinion should be obtained.
A11.8. A second episode of concussion, occurring within a period of three months will require specialist referral prior to the return of the licence.

Source: MSA Yearbook 2016, reproduced with permission from the MSA, 28 February 2017.
MSA: Motor Sports Association.

Formal motor sport guidance

The ongoing desire for formal guidance regarding concussion in motor sport has recently been characterised by an online survey published in AUTO+ Medical, where 65% of the medical participants found it difficult to assess a competitor for concussion and over 99% requested further guidance regarding returning to race decisions.[29]

The FIM publish a comprehensive Medical Code, which advises that: "Assessment of the injured rider and return to competition should be in accordance with the guidelines for the assessment and management of concussion as contained within the International Consensus Statement on Concussion in Sport Zurich 2012".[15] In a direct statement of concordance to the above, the guidelines also state that: "the rider should immediately be excluded from competition for at least the rest of the event" if a concussion is diagnosed. Return to race is then dictated by documented formal assessment of resumption of: "normal neuro-psychological function", where the use of ImPACT or functional MRI is advised. AMA ProRacing similarly advises 'passing' of an ImPACT assessment prior to returning to competition,[35] a stance which is replicated by Indy Car.

The UK Motor Sports Association (MSA) introduced its first concussion guidelines into the MSA Yearbook in early 2016 (Table 2), advising removal from competition for 14–21 days after a diagnosis of concussion.[36] Similarly, Speedway New Zealand mandates a 22-day stand down period for any driver diagnosed with concussion, which can be reduced to an absolute minimum of 15 days, pending formal medical assessment and Board approval.[37] There are no formal

published guidelines from NASCAR or the FIA. Regarding the latter, concussion seems only to be loosely covered by Article 1.5.3 of Appendix L to the International Sporting Code: "any health problem that might, because of its nature or the treatment required, result in consequences that are harmful to participation in motor sport including in case of an accident".[38]

AREAS FOR RESEARCH AND DEVELOPMENT

The medical management of concussion

Frontiers in the medical management of concussion in motor sport are broadly two-fold. The first is clinical and relates to the trackside diagnosis of concussion and the return to race decision; the second involves collaboration with engineering colleaguesa and relates the mitigation of translated forces during impacts.

As elucidated in a systematic review of the ImPACT assessment, new directions for objective assessment in concussion include balance testing (such as the sensory organisation test), ocular-motor assessment (visual ocular motor screening) and cognitive-balance dual tasks paradigms.[16] These tools must be utilised carefully however with stringent normative values, since research has proven that motor sport athletes attain superior visual performance when compared to controls.[39] Furthermore, accurate diagnosis of concussion requires competitor engagement and education; a recent survey described previously from AUTO+ Medical highlighted that 76% of participating

Formal diagnoses of concussion have increased in BTCC, with 38 incidences observed from 2012-16, compared to incidences of 0-1 per year in the early 1990s.

> **“CHAMPIONSHIP-WINNING VEHICLES WITH POTENTIALLY HIGHER ACCELERATION MUST BE MITIGATED BY DRIVER PROTECTION SYSTEMS”**

competitors would like to learn more about concussion.[29] Worryingly, half of the reported concussive episodes in this study had not been discussed with a doctor, further indicating that concussion may be more prevalent than is currently understood.

The notion of incident analysis informing technological advances in motor sport was proposed by Olvey et al.[40] as early as 2004 and has recently been translated to the use of simulated driving studies.[41] The latter is supported by evidence from 2006, which concludes that simulated driving is comparable to road use but lacking the emotional component.[42]

Engineering a reduction in concussion

Driver safety has become a cornerstone of motor sport regulation, embraced by engineers and medical professionals alike. However, the requirement for championship-winning vehicles with potentially higher longitudinal and lateral accelerations has to be carefully mitigated by driver protection systems, which in themselves can add extra mass, cost and other unforeseen effects. The relationship between medical and engineering professionals was concisely summarised by Lippi et al.[43] Andy Mellor, Senior Research Engineer at the Global Institute for Motor Sport Safety, provides insight into these technical challenges.

Head protection in motor sport is of vital importance and can be lifesaving. A serious incident will not only impart considerable accelerations to the vehicle chassis and directly to the competitor but also cause significant relative velocities between the head and the in-car environment. A head protection system must therefore be designed to manage these forces. The primary aim of this equipment is to absorb significant amounts of energy, whilst ensuring that the loads, pressures and accelerations imparted to the head do not exceed injury thresholds. From an engineering perspective, the greatest challenge in motor sport lies in mitigating the relatively high change in velocity together with the very short stopping distance available on track. Currently, helmets used in motor sport are typically homologated to absorb energy at acceleration levels of up to 300 g. This threshold exceeds that of the headrests in single-seater vehicles, which are designed for 275 g for severe and 100 g for minor accidents. These latter values are considered a compromise to ensure head protection over a full spectrum of accident severities, whilst ensuring optimum protection via the helmet. The threshold g values for severe head injury were clarified by analysis and reconstruction of 10 motor sport accidents with significant head injuries, concluding that 100 g corresponded with head accident injury severity (AIS) score 1 and 300 g with head AIS score 3.[44] To date, no studies have investigated the g forces specific to the development of concussion, although the threshold is suspected to be considerably below 100 g.

An important future contribution to the technical aspect of motor sport will come from the analysis of racing incidents. The

preferred data capture method in professional motor sport currently is the deployment of in-ear accelerometer systems which are used in Formula 1 and Indy Car. The Formula 1 system measures 0 to ±400 g in three orthogonal axes, at a sampling rate of 1000 Hz. A single unit is moulded within the silicon earplug for each ear, incorporated within the communications system. In addition to measuring linear motion, there is theoretical potential for the measurement of rotational acceleration. By employing a six-axis linear accelerometer system, it may be possible to measure rotational accelerations about the X and Z axes. This approach relies on measuring the difference between linear accelerations from the left and right ear pieces. Mathematically, a pure rotational acceleration of 10,000 rad/s/s about the Z axis (yaw) would cause a linear acceleration of +50 g in one ear and −50 g in the opposite ear. If future accelerometer systems had an overall accuracy of ±5 g then a resolution of 1000 rad/s/s could be achieved, which could greatly assist in the elucidation of the causative forces for concussion. Secondly, to measure rotational accelerations about the Y axis it may be possible to fit micro rate-sensors, a prospect currently under investigation. Finally, high-speed filming could be employed to determine rotational position, differentiating for both velocity and acceleration. The theoretical basis for this measurement has been proven mathematically, such that with adequate frame rates and resolution, it would be possible to measure velocity accurately and acceleration to a certain extent.

CONCLUSION

The most influential medical professional in the motor sport field was undoubtedly the late Neurosurgeon Professor Sid Watkins, former President of the FIA Institute for Motor Sport Safety. In addition to revolutionising driver safety in motor sport, Professor Watkins assessed all injured competitors in FIA Formula 1 and the BTCC during his extended career. This singular approach to concussion is now not possible in motor sport as a result of ever-increasing race team pressures and fierce commercial interests, on a background of more prolific litigation and high-profile medico-legal rulings in other sports. In fact, there now exists a significant knowledge gap for concussion in motor sport specifically.

Extensive review of the published literature has established that motor sport has a relatively high rate of concussion when compared to other sports, but the data are variable depending on the vehicle, class/championship, country, level of competition and terrain. Furthermore, it is difficult to interpret these data since a significant proportion of the published literature is descriptive or observational. In addition, the most informative studies are retrospective and frequently rely upon emergency department attendance figures or nationally collected data, which are not specific to motor sport. Therefore, it is possible that the data presented may misrepresent the actual incidence or

“THERE ARE A GROWING NUMBER OF ADOLESCENTS IN MOTOR SPORT…THIS GROUP REMAINS UNDER-REPRESENTED LITERATURE”

The late Professor Sid Watkins oversaw massive advancements in motor sport safety during his career, including Formula One's adoption of the HANS deivce.

prevalence of concussion in motor sport. This latter idea is supported by the recent finding that the majority of competitors have historically failed to seek medical advice following a concussive episode.

In contrast, the published data for professional motor sport appear to indicate lower rates of concussion. However, there are few studies which investigate this sector of motor sport specifically, and the diagnostic criteria are disparate, largely attributable to variation in publication date. Superficial analysis of the small amount of published data indicates that American series, such as Indy and NASCAR, have lower rates of concussion than in competitive activities utilising similar vehicles in other countries. In particular, rates of concussion in the BTCC and its support series appear to be increasing; a fact which requires further investigation. Lastly, there is a growing representation of adolescents in professional motor sport, however this group remains under-represented in the published literature. Studies investigating non-professional competitive motor sport indicate that repetitive head injuries are problematic; a significant cause for concern in the developing brain of a professional motor sport athlete. However, regardless of professional or amateur racing status, there is a growing number of adolescent participants in motor sport globally, and medical professionals must recognise the

significant contribution of this cohort to concussion, especially when cognisant of the second impact syndrome.

Review of the medical literature exploring the protective measures employed to reduce head injury/concussion highlights that partnerships with engineering colleagues have been employed successfully in recent years to reduce rates of concussion. This collaborative approach may be an efficient way in which the competitive nature of the sport can be maintained in the safest manner. Furthermore, it will be vital to extend such collaboration to incident analysis where a knowledge gap exists for the threshold values for concussion. The field of motor sport, with its close links to frontiers in technology, is a fertile ground for multi-disciplinary collaboration, and this provides an excellent opportunity to elucidate the non/-impact-related causative factors of concussion and the relative contribution of linear versus rotational forces.

Perhaps the most influential decision made by a medical professional is that of a competitor returning to race after a concussive episode. Currently, competitors appear to be relatively poorly informed regarding the diagnostic criteria for concussion, with the ideology that LOC is a necessary component being perpetuated even in professional series. Additionally, there is no established 'safe period' in the literature for return to driving in general, not least for competitive activity. The 2016 Berlin update of the CISG guidelines are eagerly awaited by the medical community. Their adaptation and incorporation into readily accessible formal motor sport-specific concussion guidance is a necessity.

The current challenges in the medical management of concussion in motor sport could be mitigated by prospective, large scale, international studies of high scientific standards designed to accurately define the exact incidence and prevalence of concussion in motor sport, which remain unclear. The need for motor sport-specific studies also extends to the assessment and diagnosis of concussion; ImPACT remains the only CNT commonly utilised in the field, yet has never been formally validated for motor sport. Finally, return to race decisions could be augmented by simulated driving scenarios supplemented by eye-tracking technology and measurement of reaction times. Such studies would allow competitors to be more aggressive in their driving style, without compromising their safety, or that of other competitors, and indeed a similar approach could be utilised for specialised onward rehabilitation. The applicability of new objective diagnostic tools for concussion to highly specialised motor sport athletes could also prove invaluable.

> **"DESPITE THE POPULARITY OF MOTOR SPORT, THERE IS A MISMATCH OF RESOURCES TO MEDICINE"**

From an engineering perspective, the current technical challenges of concussion in motor sport centre around the need to balance driver safety against race team success. Despite this difficult task, there remains a significant potential to greatly improve knowledge of the physical mechanisms and thresholds for concussion by investigating and analysing motor sport incidents. The deployment of in-ear accelerometers to a broader range of championships would provide a much-needed increase in the amount of data available worldwide. The use of additional technology, such as micro rate-sensors and high-speed video, may prove valuable tools to support this analysis. These tools are limited currently only by team, championship or regulatory body engagement. Caution must continue to be employed in the interpretation of these data, however, since helmet motion may not translate to that of the head, the brain or its microarchitecture. Even with such caveats, the data from these tools may be combined to develop improved performance targets for future head protection systems, applicable not only to motor sport but also to road users.

Despite the popularity of motor sport in the lay domain and the vast amount of financial investment in the engineering aspect of the sport, there remains a mismatch of resources to medicine and a resultant paucity of medical research in the field. Concussion is an evolving problem which appears to be more prolific in some series as compared to others, yet the causative forces remain largely undefined. There exists a real progress in the global assessment and diagnosis of concussion and the prospect of new objective diagnostic tools could revolutionise the field. However, the challenge for motor sport will lie in incorporating these advances into guidelines applicable to the vast array of national and international motor sport governing bodies, across a range of amateur and professional competition.

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