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AUTO+ MEDICAL

QUICK THINKING

How the brain is becoming the next frontier for improvements in driving performance

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INTRODUCTION/

In this latest edition we examine the use of brain imaging technology as the next frontier of performance for motor sport teams. Nissan is using this technology with their Formula E drivers to help improve lap time, and potentially influence safety in their road cars.

For the first time in their 50-year history the World Rally Championship will be switching to hybrid technology in 2022, which means new safety rules for rescue and medical crews worldwide. FIA Rescue Specialist, Ian Dunbar talks through the recent training course held by the FIA together with rescue tool specialists Holmatro.

After finishing this year's IndyCar season Rinus Veekay discusses his Road Back to recovery after suffering from a broken clavicle following a biking accident during training during the season.

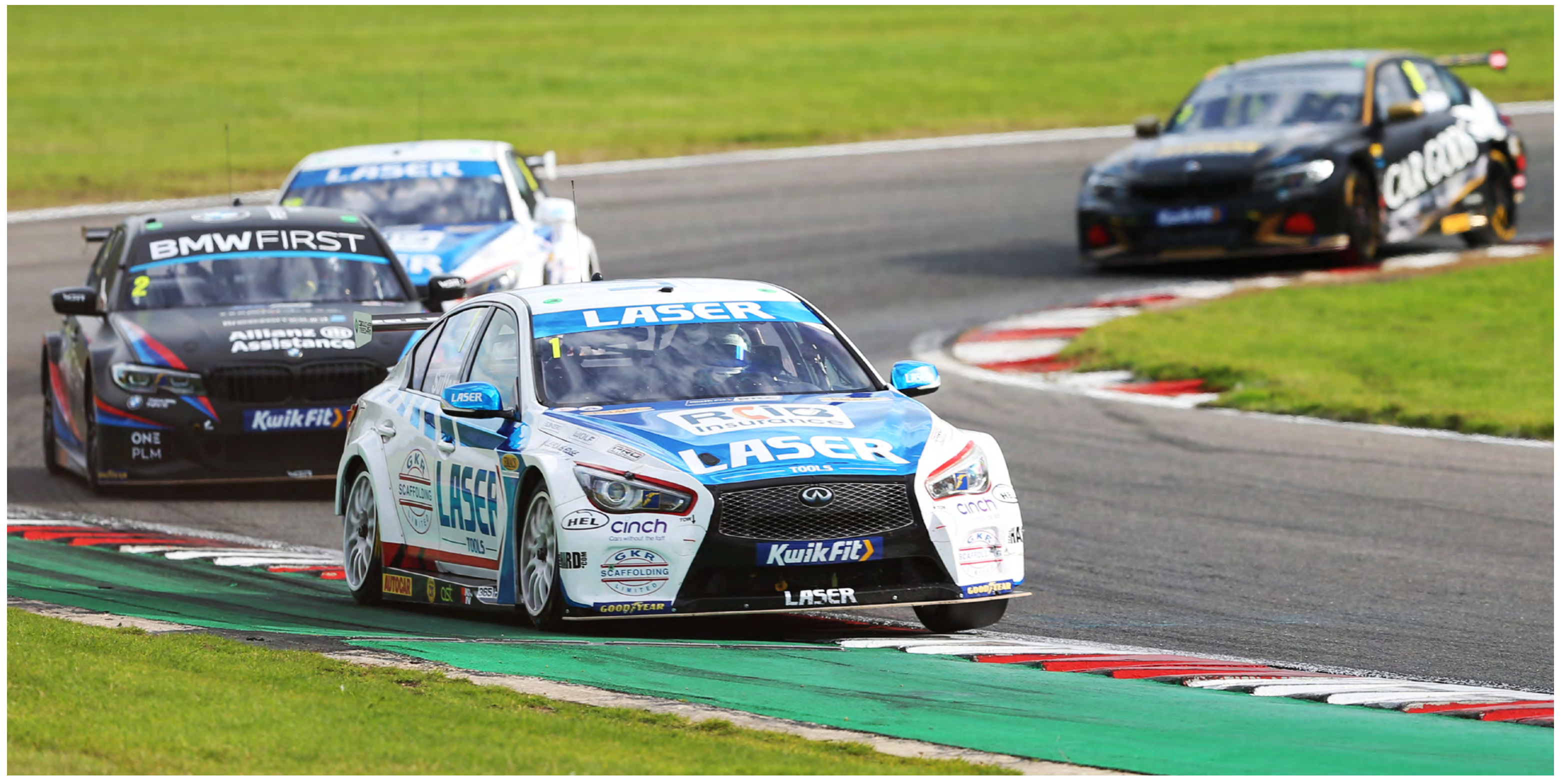
Dr Michael Henderson talks us through his career in motor sport medicine, having recently been appointed Officer of the Order of Australia in the 2021 Queen's Birthday honours list for his pioneering work in motor sport and road safety.

We also hear from Dr Osman İrez, who has worked as Chief Medical Officer at this year's Formula One Turkish GP and Rally Turkey in the WRC, and get his views from the ground in Turkey.

Our scientific article is an observational study into motorcycle accidents on racetracks and how the vital and clinical signs of a rider are gathered within the first minutes.

The Editorial Board

GLOBAL NEWS



TOCA INTRODUCE ONBOARD SAFETY SYSTEM FOR BTCC AND F4 IN 2022

All cars in the British Touring Car Championship (BTCC) and British F4 will run a new onboard visual signalling system from 2022.

The new safety system will provide a direct link between BTCC Race Control and drivers out on track. They will be able to immediately inform all drivers via their in-car dashboards of yellow flag zones, red flags, Safety Car periods, black flags, black and white flags, and other safety-related messages.

This system will further support the LED light boards and traditional flag system used by marshals situated around the circuits, which correspond with displays on the timing screen.

Developed by Timing Solutions Ltd, the innovative system also enables Race Control to track the real-time position of every car. This gives them the ability to monitor infringements such as speeding in the pit lane, overtaking under Safety Car, and not slowing sufficiently for yellow or red flags.

The system is set to be incorporated across the championships that support the TOCA support package according to Hugh Chambers, CEO of Motorsport UK.

"This is an important step in the advancement of safety for drivers competing in both the British F4 Championship and the wider TOCA support categories," said Chambers. "These onboard visual signals are also crucial in introducing young drivers to the same safety systems they will encounter as they progress through the single seater ladder towards Formula One."

SPA FRANCORCHAMPS UNVEILS SAFETY UPGRADES

Spa Franchorchamps has unveiled major redevelopments aimed at making the track safer for bikes.

The new FIM Endurance World Championship 24 hours of Spa race will take place in June 2022, and with it come a new €80m redevelopment project.

The work will focus on both the track itself and the infrastructure, with the main parts on the circuit being modified being the run-off areas and gravel traps at La Source, Raidillon, Blanchimont, Les Combes, and Stavelot.

The run-off area at Raidillon will be extended, while the chalet on the outside of the corner will be replaced with a new covered grandstand which will feature a total capacity of 4,600 seats.

With further upgrades there will be more than 13,000 seats that will be added in total, doubling the circuit's seating capacity.

Gravel traps will also be added to those areas, as part of the requirements for the circuit to meet FIM Grade C circuit standards.

It will be the first time that bike racing has taken place at the circuit since 1990, with much of the circuits layout to not be changed.

TIM MALYON APPOINTED AS FIA SAFETY DIRECTOR

Tim Malyon has been appointed as the new FIA Safety Director following the departure of Adam Baker, overseeing all safety and medical work across the FIA and its championships.

Malyon joined the FIA as Head of Research in 2019, a new role at the Geneva office that was created to oversee the growing number of safety research projects undertaken by the FIA.

He previously worked for Red Bull Racing for 12 years, having joined the team when it was known as Jaguar Racing. He worked in various race engineer roles and contributed to Red Bull's historic four Constructors and Drivers' championships.

In 2015 he moved to Sauber Motorsport as its Head of Track Engineering before going on to work for BMW Motorsport as a Chief Engineer for its DTM programme in mid-2016. After two successful years at DTM, which included one championship victory, he took on the roles of both Track Engineering Department Leader and Chief Engineer for BMW's Formula E team.

As Safety Director, Malyon will be overseeing the safety and medical developments for the FIA across its championships, alongside R&D and homologation activities for both racetrack and road.

LATEST ICMS CAFE EVENTS DISCUSS MOTOR SPORT SAFETY

I C M S CAFE

The latest International Council of Motorsport Science online cafe events brought together medical professionals to discuss developments in motor sport safety and share their knowledge in the field.

Jim Leo and Jamie Barnes facilitated the most recent Cafe with a discussion on lessons learned from training elite athletes for managing motivation, setbacks and persistence.

Trifun Dimitrijevski and Gregg Summerville explored the challenges and tactics for managing a travelling motor sport response team to ensure successful integration with local teams.

Born Vos explored the topic of psychological support following a critical incident at a motor sport event, while Shereen Habib looked at the role of 'Campfire Learning' - a way to highlight topics that can improve performance and outcomes in medical and rescue response.

All Cafes are recorded and ICMS members can access these any time afterwards here: https://icmsmotorsportsafety.org/cafe

KARTING BODY PROTECTION SUCCESSFULLY INTRODUCED

The FIA has successfully introduced Karting Body Protection (KPB) at the opening round of the European Karting Championship in Genk, Belgium earlier this year.

The combined rib and chest protector was worn by drivers under their CIK-FIA approved overalls to help them withstand heavy impacts to the torso area without injury. They will be made mandatory in all karting competitions entered on the FIA International Sporting Calendar from January 2022.

So far five equipment manufacturers in the karting world have designed, developed and homologated CIK-FIA body protection that meets FIA Standard 8870-2018. This includes Bengio, OMP, Stilo, and Tillett, which were all worn by drivers at the round in Genk, as well as Sparco more recently.

The Italian driver Cristian Bertuca, who competed in Genk, said: "Most drivers are already used to racing with a very stiff rib protector, this system adds protection to the chest. We remain free to move our arms, neck and head. You have to adjust it precisely with the straps so that you are perfectly comfortable in your seat."

The standard was developed the FIA Safety Department to prevent three forms of injury: impact with flat or curved structures; impact with steering wheel or edge of the seat; and impact with the steering column.

It can withstand 60J of energy to the chest and 100J of energy to the ribs, while ensuring the maximum force transmitted to the body is no more than 1kN during an impact. The KBP is available in both male and female versions.

The standard is the result of extensive research and consultation with the Industry Working Group to ensure that it is effective, accessible, and affordable for drivers racing at grassroots level.

EXTREME E USES AIR AMBULANCE JET AT ARCTIC X-PRIX

Extreme E used an Air Ambulance Jet at the Arctic X-Prix that took place in Greenland, provided by medical services company MDD Motorsport.

Equipped for two intensive care patients, the private jet is specially equipped for a patient that needs extensive and urgent medical assistance during transportation to a hospital. It was on standby at Kangerlussuaq Airport in Greenland ready for rapid evacuation to Iceland or Denmark if required.

MDD Motorsport were appointed to provide on-track extrication, medical support, and training for all new teams in the electric off-road racing series at the start of the 2021 season.

They also provide full air and ground medical support to FIA Formula E, the Electric Touring Car series, and electric motorbike championship Moto E.

AUTO+MEDICAL GLOBAL NEWS

NEW FIA SAFETY EQUIPMENT LEAFLET AVAILABLE FOR ALL COMPETITORS

A new safety equipment leaflet which provides information for drivers on what must be worn by competitors when they are competing in FIA competitions is now available.

The leaflet is designed to show how safety is not expensive and should always be accessible to drivers in any championship they wish to enter. The leaflet provides the differences between a base and an advanced level of protection and an equipment checklist which shows the FIA Standard.

The comparison is helpful for drivers wanting to know the type of protection provided by each piece of safety equipment, and a comparison of several parameters such as the minimum safety performance, materials, and technology used in the manufacturing process.

It provides a best-practice guide to take into consideration the parameters of safety, comfort, weight, and price to make informed decisions when it comes to purchasing safety equipment.

Drivers should also look out for the FIA hologram to ensure that each piece of equipment is genuine and identify which products have been subject to stringent FIA tests before being put on sale.

You can download it by following this link.

WRC USES ARTIFICIAL INTELLIGENCE CAMERA TO IMPROVE SAFETY

A new forward facing camera will be fitted to all 2022 WRC cars, which will have the ability to scan stages for hazards and analyse the position of spectators.

Safety of spectators has been an ongoing issue in rallying with a number of stages having to be cancelled due to fans standing in dangerous locations.

As part of plans to improve spectator safety, this camera will be placed at the front of the cars and will observe the external environment using artificial intelligence.

The project was funded by the FIA Innovation Fund and is part of the Vision Zero plan to reduce deaths across motor sport and mobility.

This AI camera technology will continually scan special stages and their direct surroundings to "identify the shapes and analyse the position of spectators in the environment," said the FIA.

The camera will feed back to rally control and help to supplement the work undertaken by the FIA Safety Delegate to address unsafe situations.

EATON REVEALS EXTENT OF INJURIES AFTER W SERIES COTA INCIDENT

W Series driver Abbie Eaton has revealed the extent of the injuries she suffered after an incident on the kerbs during the Circuit of the Americas round.

Eaton ran over one of the sausage kerbs at Turn 15 which launched her car into the air. Initially she was diagnosed with a fracture in her T4 vertebra from the impact, but later said on social media that she was diagnosed with a second fracture in her T5 vertebra.

"Bad news: Results from MRI are that I actually have two fractures in T4 & T5," said Eaton. "Good news: Fractures are currently stable, brace stays on for the 3 months, but I can START PHYSICAL REHAB! So excited to feel like I can actually start making steps in the right direction!"

Eaton faces wearing a neck brace as part of her recovery until February, and subsequently months of rehab including specialist physiotherapy and physical therapy.

A GoFundMe fundraiser was setup which raised over £20,000 to help with her recovery costs.

VIEW FROM THE GROUND:

DR OSMAN İREZ

MEDICAL DIRECTOR OF THE TÜRKIYE OTOMOBIL SPORLARI FEDERASYONU.

Dr Osman İrez is the Medical Director of the Türkiye Otomobil Sporları Federasyonu. He has worked at the Chief Medical Officer of the World Rally Championship events and at Istanbul Park for the Formula One Grand Prix.

I have been a medical doctor for 27 years and practice as an internal medicine specialist. I have been interested in motor sports since childhood, including competing in local competitions as a co-pilot in my twenties. For the past 10 years I have worked with the Türkiye Otomobil Sporları Federasyonu (TOSFED).

I work as a medical delegate at TOSFED, the country's main National Sporting Authority. This involves working as Chief Medical Officer in World Rally Championship events and at the Istanbul Park circuit for the Formula One Grand Prix. I worked as a CMO in WRC for three times at the 2018, 2019, 2020 Marmaris Rally of Turkey and the F1 races at Istanbul Park in both the 2020 and 2021 seasons.

As a TOSFED medical delegate and CMO, I conduct training and programs for the medical teams of motor sport organizations in our country.

After the international competitions held in Turkey, interest in motor sports has increased tremendously in recent years. It became one of the countries with the fastest increase in the audience and interest level in the bulletins published by the FIA. As such, many volunteer doctors, paramedics take part in national and international organizations in our country.

While there are about 30 certified doctors and 120 paramedics, around 50 doctors and 200 paramedics who have applied for training are waiting for volunteers and I think this number will continue to grow.

A regular annual training meeting is held for the training of doctors. In addition, quick practice is done by meeting before each organization. Certificates are awarded according to education degrees.

With the training sessions held for the existing team four times each year, training is provided for new team mates and once a year for new people. Those who are new who pass the test are recruited. We provide five-day training with the staff who will each come together and work for one week before there is an international event.

As I serve on the medical commission of the FIA, I am working and collaborating with many doctors from other circuits all around the world. If I could change one thing about local motorsport in Turkey, if this is possible, I would like to establish a training facility in my own country that will serve motor sports and build more circuits. With these new circuits to be built, the interest in the sport will increase many times over.

In future I wish to meet in motor sport organizations where there is no COVID disease. Doctors and ordinary citizens were very worn out during the epidemic, so I hope motor sport will meet this enthusiastic audience once again.

DR MICHAEL HENDERSON

Dr Michael Henderson is a medical professional with over 50 years of experience working in aviation, road, and motor sport safety research and administration. He was recently appointed Officer of the Order of Australia in the 2021 Queen's Birthday honours list for his pioneering work in motor sport and road safety. *AUTO+ Medical* spoke to him about his career and his thoughts on the current state of safety in motor sport.

AUTO+ Medical: What came first for you, motor sport or medicine?

Michael Henderson: For me, they have always been inextricably intertwined. I was race reporting and writing about motor sport while still a medical student and worked for the BRSCC when on vacation from Cambridge University. I started racing in a Lotus Seven before qualifying. I originally considered going into orthopaedics because the hospital where I was training, St Thomas', became well known for treating injured racing drivers, including Stirling Moss. If I hadn't favoured medicine, I would have liked to be an engineer. Eventually I found a niche that covered both professions.

A+M: Safety in motor sport faced resistance in the early years, why do you think that was?

MH: I'm not sure that resistance was ever as much of an issue as the perception that the risk of injury and death in a crash was unavoidable when vehicles were driven at the limit of control. Survival was seen as purely a matter of luck.

Motor sport has always been dangerous, but so are many other sports, and just as in these other activities competitors became habituated to danger, rationalised it, and with skill and experience tried to minimise it. "Dicing with death" was something to be admired, a feeling of immunity was universal, and the main fear was mechanical failure.

Even as late as the fifties and sixties safety was simply not seen to be an issue, and even known safety features were thought to dilute the purity of the car and the circuits. They were thought to change the very nature of the sport and threaten the image of the racing driver as a hero to be worshipped.

A+M: It's impossible to think of a driver setting foot in a car without a six-point harness, do you think that was the turning point for many major safety advancements (i.e. HANS, safety net, halo)?

MH: There were essentially no belts ever used in open competition cars in Europe until the late sixties. I had proved statistically in my 1967 study of race crashes in the UK that it was safer to stay in the car in a crash than to be thrown out, contrary to general opinion

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at the time. Because of the steeply reclining driving position that was emerging, it was clear to me that crutch restraint was a necessary component of the belt system to prevent submarining, and I published both the stats and the six-point belt concept in many articles and comprehensively in my 1968 book, Motor Racing in Safety. The foreword for the book was written by Louis Stanley, who had just established the Grand Prix Medical Service and was chairman of BRM. Jackie Stewart, a BRM driver at the time, was already urging for more and better circuit safety, and Stanley did not need much convincing to put a set of belts into the car, the first in Formula One.

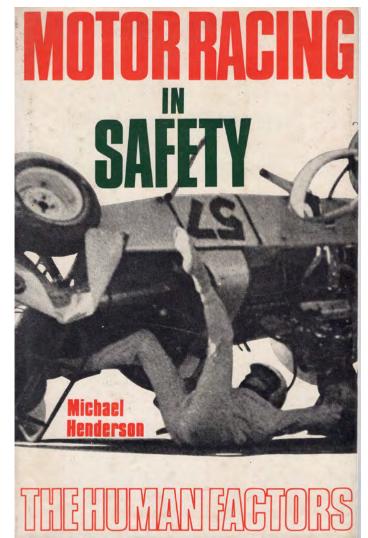
Throughout 1968 belt use in F1 went from one (Stewart) to 100 percent, with many drivers escaping injury through belt use. Others – including Jim Clark – died or were being injured in crashes unrestrained. Immediately following Stewart's prominence and persuasive skill which revolutionised the general approach to circuit and administrative safety, Sid Watkins and Bernie Ecclestone brought permanent medical centres to the circuits.

So yes, the introduction of six-point belts was a highly effective turning point for crash protection in competition cars at a time that everything was beginning to change for the better. The future for race car safety was demonstrated by the 1969 Pininfarina/Ferrari safety concept safety car, the Sigma Grand Prix, for which I was one of the concept team. It embraced a host of innovative safety concepts, including head restraints and data logging for example, all of which have since become mandatory in the top FIA categories. The car is still on show worldwide.

A+M: You were instrumental in establishing Australia's first road crash research and test unit 'Crashlab', how much has road safety improved in all areas since its opening?

MH: Australia had a dreadful reputation for road safety in the late sixties, when my wife and I moved out to the country of my forebears. The road death rate had been inexorably rising since records began. In 1969, with strong support from the state and federal governments, we in the new Traffic Accident Research Unit (TARU) in Sydney became among the leaders of a campaign to introduce the sciences of public health and engineering into road crash injury countermeasures. The driver was no longer to be seen as the only reason for crashes, and we shone light on the contribution of poor vehicle safety, roads, and traffic rules. Our first major step was to draft regulations to make seatbelt wearing compulsory, a rule that became nationwide in 1972, the first in the world and now universal.

In 1970 the road death rate in Australia peaked at over 30 deaths per 100,000 but levelled out and started declining by the end of the decade. Currently the death rate



Throughout 1968 belt use in F1 went from one to 100 per-cent

The six-point belt concept was first published in his 1968 book

is less than five per 100,000, good by the international standards which are still, slowly but steadily, improving around the world.

A+M: Are there many crossovers from motor sport in your research into preventing road trauma?

MH: Yes indeed. I have been a motor sport enthusiast and club racer all my life and well understand that the basic principles for reducing death and injury on public roads and in competition are precisely the same. The principles apply to scientific research and its application, modifications to vehicles

"I HAVE BEEN A MOTOR SPORT ENTHUSIAST AND CLUB RACER MY WHOLE LIFE"

to minimise the transfer of impact energy to the human body, the creation of an environment that is as forgiving in crashes as possible, and the support of the system by sound regulation and enforcement. A simple example is that my work on race harnesses led directly to the design, standardisation, and mandatory use of multi-strap child restraints in Australia.

A+M: What do you think are the main concerns in road safety going forward?

MH: Different countries have different priorities. However, there are issues which have international significance. For example, demographic changes have shone attention on older drivers and vulnerable road users such as pedestrians, motorcyclists, and cyclists, and all have different safety requirements within the complex safety system. The management of speed will always be controversial within a system that only exists to provide mobility. In Australia nearly two-thirds of deaths and injuries occur in rural towns and on rural roads. Turning to vehicle safety there has been much progress in crash avoidance, but these measures filter only slowly down the fleet from the expensive end. Driver fatigue and distraction will continue to be major problems. "Vision Zero" is a handy term to encapsulate an aspiration, and is employed by the FIA and governments alike. While I hail a visionary

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approach, determined and cost-effective implementation of known measures is the dirty work that takes us onwards.

A+M: You were appointed Officer of the Order of Australia 2021 Queen's Birthday honours list for your work in motor sport and motor vehicle safety, how important was that recognition for you?

MH: Oh, vastly important, as well as being totally unexpected. I was humbled. The fact is that in both motor sport and road safety there have always been scores and now many hundreds of very clever people in the world tirelessly working on these issues. I have been privileged to work with, and learn from, many of the best.

A+M: What would you say has been your biggest challenge working in motor sport so far?

MH: That's a hard question, because the acceptance of safety as a component of the sport has vastly increased since I started work in the field. The challenges at that time were centred in getting people to understand that competitors in all categories and up to Formula One who make a mistake or misjudgement should not be penalised by injury or death.

The fundamental challenge for all of us following events such as the Le Mans crash in 1955, Jim Clark's death in 1968, and the deaths of Senna and Ratzenberger in 1994 after 12 years since a fatality in F1, was to save the sport from acrimony and censure by prompt and serious attention to greater safety. Another specific challenge, in which I have long personally been involved, is to manage safety in historic racing, from club events to historic F1. This is really hard!

Sigma GP safety concept F1 car

A+M: What is the most rewarding thing about working in motor sport?

MH: I am rewarded by the camaraderie and friendship of all participants, and at the highest level in FIA circles to learn from the extraordinary expertise of the engineers and medical personnel at the sharp end of safety improvements in this highly technical world. In any case, for my own part, motor sport has always been a great deal of fun!

A+M: If you could improve one thing in motor sport safety, what would it be?

MH: It would be the better systematic collection and collation of mass data to provide a bigger picture. A few years ago, my world-wide analysis of volunteer-collected data showed how death numbers in rallies were rising, as against a general decline in other categories of the sport. This caused a reorientation of efforts in many administrations, including Australia, where an extensive review of rally safety was soon initiated.

A+M: Anything else to add?

MH: Working with the safety and medical people in the FIA for several years has been an inspiring experience, as has been my work and association with Motorsport Australia, our National Sporting Authority. It's all been a privilege.

"THE MANAGEMENT OF SPEED WILL ALWAYS BE CONTROVERSIAL"

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FEATURES

QUICK THINKING

What exactly is it about racing drivers that makes them so fast? Is it an ability the average person simply does not possess, or can it be taught or even programmed? *AUTO+ Medical* examines how race teams are analysing the human brain for the answer.

There are approximately one billion neurons in the brain that enable us to see, think, and do things. For racing drivers, when they are out on track these sensors are heightened as they turn the wheel to extract performance and lap time.

Studies have been done previously by Ford Performance which have measured the concentration levels of a racing driver compared to drivers in normal cars on the road. These initial tests have found that professional drivers perform up to 40 per-cent better than the average person, as a racing driver can use much more of their brain's maximum capacity when it comes to decision making.

While these studies provided a definitive answer on how a racing driver can focus on a task, which makes their reactions vastly different to a normal road car driver in split-second decisions, it does not highlight how this can be examined to extract even more performance on track.

Now, some automotive researchers believe that being able to measure brain activity

“WE WANTED TO MAP THE BRAINS OF OUR PROFESSIONAL DRIVERS”

Buemi and Gunther were used as part of the study by Nissan

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will be the next frontier of performance for race teams, as they seek to extract more performance from drivers by looking at exactly how their brain reacts to their inputs on track.

Dr. Lucian Gheorghe, Senior Innovation Researcher at the Nissan Research Center in Japan and a leader in the field of brain analysis, is leading a study of how electrical stimulation can enhance the brain's ability to learn new skills and retain them.

By applying these learnings to Nissan's technologies, Gheorge and his team believe it is possible to improve driver performance, not only in the average road car user, but also professional race drivers too – like Nissan Formula E drivers Sebastien Buemi and Max Günther.

Tommaso Volpe, Nissan's Global Motorsports Director explains how this project began with wanting to see the difference between professional drivers and normal road car users, and where they hope to take it in the future.

“We wanted to map the brains of our professional drivers, to see first what is the difference between a professional driver and a normal road car user while driving,” explains Volpe.

“An ambition for the future, if we can achieve it, is to create a training programme which might enhance the performance. Why not take advantage of this research to gain this additional performance?”

Gheorghe, who has worked with Nissan for more than 15 years, is the man, as Volpe describes, who's always thinking “how cars will be in five to ten years from now.”

“I am the leader of human-based research,” explains Gheorge. “Whenever someone wants to start a new project learning how our body

works, or some bio-measuring or so on, they usually come to me for advice on how it should be done.”

“At Nissan we've spent almost 15 years looking at how our primary and secondary visual cortex reacts to visual stimuli. Measuring brain activity gives you access to the most honest reaction of a human being, and also, it doesn't have to be a person who's highly qualified.

“You can understand how your actual car customers would be reacting, or using a certain system.”

Gheorge explains two projects currently in the works at Nissan, including ‘Brain to

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Vehicle' - a project to synchronise humans' reaction to an autonomous vehicle and another called 'Brain to Performance' - looking at how a driver's skills can be enhanced to fully experience what the vehicle can offer.

"It's pointless to have a very nice machine that you cannot control," he adds.

WORKING THE WHEEL

At the heart of Nissan's research is an eagerness to understand what happens in the brain of professional drivers, and how this differs to the average person. Are there clear differences, and can these differences be simulated, or even accelerated?

"With very, very good drivers - like our Formula E drivers - this is the most difficult task. What can we do to help our drivers?," asks Gheorge.

"We started this year looking at how their brains are working. We asked them to drive the simulator and did some recordings and some MRI. During the next season, we'll add more training processes to see if we at least feel there's a small difference on top of what's happening during their usual training."

Has this been done before? "Not that I know," says Gheorge. "But then, motorsports is so secretive, if I go to a Formula 1 team they will say 'maybe we are doing something, maybe not.'

"In terms of training for Formula E, Formula 1 or racing in general, this direct methodology, I'm not aware of [any other studies] like this, but the US Ski Jumping team used electrical brain stimulation and it did show an increase of something like 40 per cent shorter reaction times.

"With the tDCS - transcranial direct current stimulation - they showed that acquiring this repetitive skill is 40 per cent faster than without. It's a pretty interesting area, because for us, what we don't know is skill retention over a long period of time.

"Like riding a bicycle after five years, you can go back and still do that. If you learn with brain stimulation it happens a lot faster, [but] is the retention also better or is it weaker after long periods of time?"

With Formula E cars said to be amongst the most complex single seaters to drive - a claim backed up by many drivers on the grid – Nissan believes that there are a lot of areas that can be measured to further help on-track performance an ultimately extract lap time.

"There are some very nice studies that look at synchronicity between brains doing the same task, and this is exactly what happens in the paddock," says Gheorge

"You have 20 engineers looking at the same type of data from different angles and coming up with an answer. So that's another very nice path that could be studied and something we could do, but this year, we're looking at the drivers per se.

"We're looking at how the brain changes when you train. We have this internal training programme for our young drivers, the ones that test vehicles. After three days of pretty strong training, we did an fMRI before and after looking just at the structure of the brain. We could see small parts being changed. It's physical proof of the encoding of skills.

"We also looked at mid-level drivers' brains compared with very weak drivers, and we saw parts of the motor cortex being better connected to parts of the primary visual cortex. We also saw parts of the hypothalamus being larger than for weaker drivers.

"The last one was pretty interesting, because these were drivers that were doing longer races, eight hours, and so on. This means they have developed this skill of being able to consciously survey their physiological state.

"It means we could have a chance to increase some connectivity paths in the motor cortex, or the synchronicity between visual cortex and motor cortex. The question we're trying to answer now is can we transfer that into driving skills?"

Surely the simplest way to measure the effectiveness of these studies would be to look at the impact on lap time? But it's not quite as straightforward as that, explains Gheorge.

"There are many factors right? It's being able to react quickly to the environment. It's not 100% going to connect to lap times," he says.

"The hope is that once you have better tools, then the drivers should have, at least statistically speaking, more chances to use

> **"YOU HAVE 20 ENGINEERS LOOKING AT DATA FROM DIFFERENT ANGLES"**

Nissan believes data from its Formula E drivers can help inform driver safety on the road

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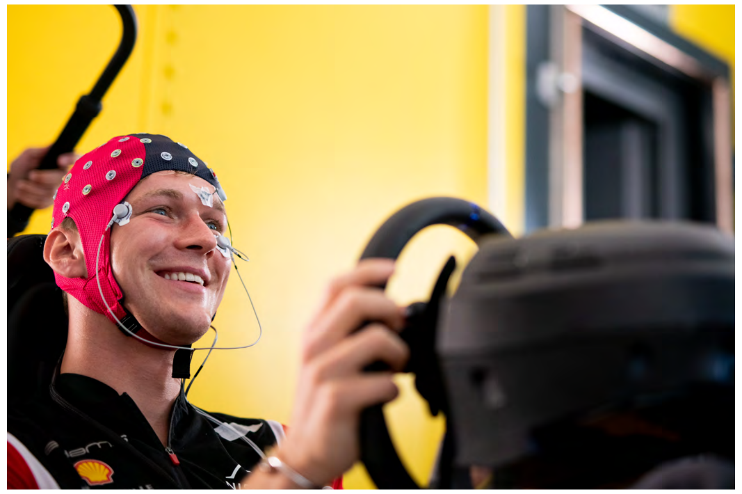


those tools and to transfer them into better lap times."

As Volpe adds, performance in Formula E can often be found through marginal gains, such is the close competitiveness of the field.

"The gap in lap times between two drivers is very, very small, sometimes 22 drivers covered by one second. This is something we don't see happening in any other motorsport.

"So we think these kinds of tools might be even more relevant in motorsport, where we're talking about sometimes losing two or three positions because the reaction speed in one corner was likely slower.

These might not have an impact visible in the final result in Formula 1, if we can achieve these results [in Formula E] it will probably make a difference."

MIND GAMES

Nissan's driver line-up in Formula E is an intriguing one. On side Sebastian Buemi, a former champion of the series, and the other, Max Günther, a bright young talent almost a decade Buemi's junior. Each with contrasting experience levels, but as racing drivers, both were equally as intrigued by Nissan's research.

"Well, the first time we mentioned it, it sounds a bit scary, but drivers are highly competitive so anything that can help them improve their performance is very welcomed," says Volpe.

"With Max and Seb we have two very curious individuals. They both joined the programme with a lot of curiosity to fully understand the brain while driving in a high-performance context.

"Of course, if we could improve their performance, they'd be super happy, and I guess this is what motivates them the most. Prototype drivers in particular tend to be very tech minded and interested in science, because they're regularly talking with engineers.

"In Formula E they talk a lot about software for energy management, which is very complex, much more than Formula 1. So, you tend to have people who are fully interested in this sort of research and Max and Seb were not an exception."

With Nissan already at an advanced stage with these studies, do they expect others to follow suit? Gheorge believes their differing philosophy around autonomous vehicles already sets them apart from their competitors.

"Nissan was the first company to start speaking about AI to enhance the human being, not AI to replace the human being. That was what we were saying, how we synchronise the two instead of putting the driver asleep and making a car that can take you somewhere," he explains.

"When we are talking about that, all the other manufacturers were saying 'we'll build a better AI to drive the car faster', we were saying 'we will build an AI to enhance the human being'.

"Usually, it happens like that. If my nose says this is a tech that should be something we follow, then there's a good probability that many others in this industry will be following."

As one of the world's largest automotive manufacturers, Nissan is always looking to transfer its learnings from race car to road car, but that transfer of technology extends to much more than just battery development.

Nissan's roadmap includes an ambitious plan to enhance the skills of their customers as much as it is to design and build smarter vehicles.

> **"NISSAN WAS THE FIRST COMPANY TO TALK ABOUT AI TO ENHANCE HUMANS"**

"If we had a very nice training setup - you go online to Nissan's dealerships, you get a set at home, train and then you get on the road - you could see 'OK, this was me last year, and this is me now', this would be a super ideal world. It's not far off," says Gheorge.

"If you can go back a better driver with a better car, I think it would be a proposal that our customers would accept. Even as I say it, it still sounds science fiction, but that's the idea.

"Instead of designing systems to make people safer, I say we try to design a system that electrifies the experience of the individual that gives you more chances to enjoy the ride."

Nissan want to understand how Formula E drivers' brain functions differ to average drivers

ELECTRIC EXTRICATION

In 2022 the WRC will introduce hybrid technology for the first time, which means new safety rules for rescue and medical crews worldwide. *AUTO+ Medical* examines the latest training programme delivered by the FIA and official rescue tool supplier Holmatro.

By Ian Dunbar, FIA Rescue Specialist

As the FIA World Rally Championship moves to hybrid technology in 2022, which will debut at Rally Monte Carlo in January, it also must introduce a new e-Safety program to help medical and rescue crews worldwide deal with the effects this technology will have on their operations.

Each WRC event is unique and different with varying scenarios when it comes to how a car can be accessed when it is involved in an incident on a stage. The new Rally1 hybrid rules will see the cars use a 3.9kWh battery along with an inverter/Battery Management System and 650V Motor Generator Unit.

While the battery system will be housed in a carbon fibre shell to stop flammable liquids

AUTO+MEDICAL FEATURES

such as engine or gearbox oil from spilling onto the MGU or other hybrid elements, it is important that rescue crews understand the risks involved with electrical systems and driver extrication before participating in any on-track activity.

FIA Official Rescue Tool Supplier, Holmatro, has proved its credentials as a leader in manufacturing rescue equipment for safe and quick extrication since 1991 in IndyCar, which is why they are suited to provide the tools for such a significant change in technical regulations.

Together with Holmatro, the FIA delivered a three-day training course to showcase the operational impact that may affect medical and rescue response worldwide from the start of the 2022 season. The training event took

“EACH WRC EVENT IS UNIQUE AND DIFFERENT WITH VARYING SCENARIOS”

place at the company’s headquarters in Raamsdonksveer, Netherlands, giving responders the opportunity to ask questions in relation to training, equipment, and process.

The event was run in a COVID-19 safe environment, with FIA requirements exceeding local and national guidelines including the requirement to take a pre-event PCR test which identified two positive cases

Three-day training was delivered to medical and rescue crews

prior to the individuals traveling from their home country.

The main aim of the event was to update the attendees on the current status of the FIA operational e-Safety program in relation to WRC and introduce the technology that will be used for the first time in the championships 50-year history. The training session put particular focus on technical intervention, scene safety and incident command and control.

Personnel from FIA Medical and Rescue department, FIA Safety Department, Compact Dynamics GmbH (the suppliers of the hybrid unit) and FIA WRC Medical Delegate, Dr Cem Boneval got involved, assisting with delivery were experts from Holmatro, medical and rescue personnel from UK and Spa Francorchamps Extrication Team under the guidance of FIA World Endurance Championship Medical Delegate, Dr Christian Wahlen.

The three days were operationally focussed with mainly practical sessions and key messages being reinforced, along with theoretical input and professional discussions. The invited audience included medical and technical rescue personnel from 14 National Sporting Authorities (ASNs), with a further three clubs joining online due to travel restrictions imposed by Covid-19. The attendees were Chief Medical Officers, Deputy Chief Medical Officers and technical extrication and technical rescue personnel.

ASNs represented were Greece, Estonia, Croatia, Finland, Sweden, UK, Republic of Ireland, Italy, Monte Carlo, Mexico, Spain, Portugal, and Kenya. Delegates from New Zealand, Japan and Italy joined online for some sessions.

Developed by FIA Rescue Specialist, Ian Dunbar and Dr Cem Boneval, the program included all operational aspects of medical and technical response with the necessary considerations for e-Safety applicable from next year. This included the following sessions:

SCENE SAFETY AND INCIDENT COMMAND AND CONTROL

A theoretical presentation and discussion hosted by Dr Ben Shippey, Chief Medical Officer of Rally Great Britain was followed by a practical exercise where the attendees used a simulated crash scene to identify hazards, implement control measures, consider the management of people and resources. This promoted some debate especially around roles and responsibilities in relation to command and control.

USE OF HYDRAULIC RESCUE TOOLS FOR TECHNICAL RESCUE OPERATIONS

With this event being held at Holmatro production facility, rescue tools were plentiful, and attendees were presented the very latest generation of ‘Pentheon’ tools as well as being taken through the challenges of the latest vehicle construction in relation to WRC cars. Both the outer chassis construction (A and B pillars) and roll cages were available for cutting. For most, this was the first time they had the opportunity to reform and cut a WRC roll cage in a training environment.

MEDICAL RESCUE EQUIPMENT AND PROTOCOLS

Following a theoretical presentation and discussion hosted by Dr Cem Boneval, a demonstration from the extrication team from Spa Francorchamps led by Dr Christian Wahlen, attendees were able to demonstrate their extrication skills on a wide range of vehicles in different orientations. Some of the medical equipment had not been seem by some attendees so this proved to be an excellent session. Additional discussions considered the use of KED devices and cervical collars in the pre-hospital environment.

WRC 2022 HYBRID UNIT SPECIFICATION AND DETAIL

Electric drivetrain company, Compact Dynamics GmbH, presented the specification and operational considerations of the new hybrid unit. As this was the first time the attendees had seen the technology for 2022 it promoted a lot of discussion and questions around safety and how it affects current approach and extrication protocols.

FIA OPERATIONAL E-SAFETY EQUIPMENT AND PROCEDURES

FIA Senior Safety Engineer, Yvan Devigne presented the FIA Operational e-Safety Project which has been implemented in several FIA Championships and will apply to WRC from next year. He underlined the new roles (e.g. FIA e-Safety Delegate) and the briefings and e-Learning packages that will be available. In a practical session, Yvan also presented the operational e-Safety equipment to be used by responders.

TECHNICAL RESCUE TECHNIQUES INCLUDING INITIAL ACCESS, INTERNAL SPACE CREATION AND VEHICLE RELOCATION

Ronald de Zanger and Marinus Verweijen from Holmatro demonstrated the latest techniques for gaining access and creating space with hydraulic rescue tools. The interactive session also provided opportunity for all attendees to have some time with the tools in their hands. Another session focused on vehicle relocation, a concept where the vehicle can be moved prior to the extrication of the driver/co driver. This clinically led process was well received and has the aim of improving scene safety and access in an effort to reduce scene times.

At the end of the 3 days, there was a panel discussion where stand out discussion points were revisited and further debated. These topics focussed on operational e-Safety, and all agreed that this evolution in WRC requires us to re-evaluate some of our training, operational methodology and approaches both from a medical, extrication and technical rescue perspective.

All attendees received a certificate of attendance and a commemorative T-Shirt courtesy of Holmatro and made their way home happy but very tired after a long three days.

“RESCUE CREWS SHOULD UNDERSTAND THE RISKS WITH ELECTRIC SYSTEMS”

AUTO+MEDICAL FEATURES

THE ROAD BACK:

RINUS VEEKAY

The IndyCar rookie talks AUTO+ Medical through his road to recovery after breaking the clavicle in his left shoulder during a cycling accident in between the Road America and Detroit rounds of this years season.

In between the IndyCar double header of Road America and Detroit in June earlier this year, Rinus Veekay was out cycling with his physio as part of his training. Just 20 miles into the trail he was launched over the handlebars of his bike and landed hard on his shoulder. The 21-year-old, who won his first IndyCar race at Indianapolis earlier in the year racing for Ed Carpenter Racing, was taken to hospital nearby and diagnosed with a broken clavicle in his left shoulder.

After spending the initial few days at Hoberts County Hospital near Detroit, he was transferred to a hospital in Indianapolis on the recommendation of IndyCar and was treated with surgery by the same doctor that treated Robert Wickens, Dr Tim Weber. With the Detroit round too soon after his surgery, Veekay would be replaced by Oliver Askew for this round, and would spend the next two weeks recovering. He would return for the Mid-Ohio race in July. *AUTO+ Medical* spoke to him about his bike accident and road to recovery.

AUTO+ Medical: **What happened?**
Rinus Veekay: I was on a bike ride between two races back-to-back, one in Detroit and one in Road America which is just two hours north of Chicago. We were staying that week in Chicago, and I decided to do a bike ride somewhere from Detroit to Chicago which would be 70 miles and only 20 miles in I was on the ground. I launched over the handlebars of the bike, and I didn't feel any pain or anything, but it was a clear big break and I had to go to the hospital. At first it was Hoberts County Hospital, which was just a hospital that took care of me when I fell off the bike and went into the ambulance. I went into there and called my team manager, I was only three hours from Indianapolis which is the headquarters of IndyCar. They had really good doctors that could do the surgery for me, and then IndyCar arranged surgery for me the next day. I got surgery from the same doctor, Dr Tim Weber, that treated Robert Wickens after his accident, so I knew I was in good hands. I got surgery and my collarbone plated and once that happened, I went into full recovery mode to strengthen my shoulder.

A+M: **What was the rehabilitation process?**
RV: I worked together with my personal trainer, Raun Grobben, so I have him 24/7 helping me and making sure I was doing the right things. He did some work with the Red Bull juniors a

few years ago which I how I met him. I went to a clinic close to where I live who also worked with Juan Manuel Correa after he had his big crash in Spa, and I think he lives close to it in Miami, so there were different doctors every day but with my personal trainer we did some physio stuff. I did do a lot of physical therapy, including dry needling and cupping,a making sure all the muscles around it were back in the right place and were taking the pressure off those. I did this twice a day for 90 minutes of hyperbaric treatment, so I went into a hyperbaric oxygen chamber and did that for 10 days while I was in Fort Lauderdale before the next race. With doing that and little exercises myself to get the blood flow going, strengthening it up, I got back to 90% probably just over a week after the crash.

A+M: How long was it before you got back into the car?
RV: I think since the bike crash it was probably 10 days, so I got back in quite soon after. I actually got a message from Shane Van Gisbergen who races in Supercars Australia, and he gave me some tips about hyperbaric treatment and about how he also broke his clavicle after a crash and was back into the car after seven or eight days. I went with his advice, and I feel like it did speed up my process.

A+M: Were there any specific exercises you had to do?
RV: At first, I had a lot of trouble just lifting and raising my arm in front of me to the side, so I one tendon that was stuck behind the bone in my arm, so I couldn't really move my neck to one side from my right ear to my right shoulder. We were doing low resistance with some shoulder work and everything to get the bicep tendon back to its original form. This was to ensure I'm not overworking that collarbone. It felt like it was super strong, but all the muscle tendons around it which had a big shock because of surgery.

A+M: When you got back into the car was there any adaptations you had to do?
RV: There was one thing we did, so we've got the HANS device which normally presses on your collarbone. I had no pain moving my arm but where the incision was, that skin was just very sensitive. So, we made a lot of foam that went next to the collarbone at both sides, to ensure I wasn't putting too much pressure. I was driving and there were no problems at all, but just during the race I had some cramps on the back of my shoulder just because I hadn't

"THE TEAM HAD EXPERIENCE WITH ANOTHER DRIVER WHO HAD A BROKEN CLAVICLE"

really moved my arm for a week. I felt like there was probably a little bit of over exhaustion coming from nowhere, but after everything I could focus purely on racing, and I had no big issues.

A+M: Did you do any sim work before you got back into the car?
RV: I did not go to the sim because I didn't feel strong enough yet and I really needed three more days. A practice session on the race weekend was my first time back in the car in Mid-Ohio, so quite a difficult track. I wasn't really worried at all; the team had some experience with another driver who had a broken clavicle – Josef Newgarden five years ago – before I broke mine. So thankfully they knew what to do and the challenges that I would face.

A+M: What advice do you have for drivers that suffer the same sort of injuries?
RV: I would say that other drivers should try to get their recovery going as soon as possible. It's always a big shock whenever you break anything in your body, but just move forward, get the recovery going, and try all the options that you have in front of you.

Veekay won a race earlier in the season at Indianapolis

AUTO+MEDICAL SCIENCE

SCIENTIFIC ARTICLE:

VITAL AND CLINICAL SIGNS GATHERED WITHIN THE FIRST MINUTES AFTER A MOTORCYCLE ACCIDENT ON A RACETRACK: AN OBSERVATIONAL STUDY

Karin Hugelius, Jerry Lidberg, Linda Ekh & Per Örtenwall
Sports Medicine - Open

ABSTRACT

BACKGROUND
Little is known about vital signs during the very first minutes after an accident. This study aimed to describe the vital signs of motorcycle riders shortly after racetrack crashes and examine the clinical value of these data for the prehospital clinical assessments.

METHODS
A retrospective observational cohort based on data from medical records on 104 motorcycle accidents at a racetrack in Sweden, covering the season of 2019 (May 01 until September 17), was conducted. Both race and practice runs were included. In addition, data from the Swedish Trauma Registry were used for patients referred to the hospital. Kruskal-Wallis test and linear regression were calculated in addition to descriptive statistics.

RESULTS
In all, 30 riders (29%) were considered injured. Sixteen riders (15%) were referred to the hospital, and of these, five patients (5% of all riders) had suffered serious injuries. Aside from a decreased level of consciousness, no single vital sign or kinematic component observed within the early minutes after a crash was a strong clinical indicator of the occurrence of injuries. However, weak links were found between highsider or collision crashes and the occurrence of injuries.

CONCLUSION
Except for a decreased level of consciousness, this study indicates that the clinical value of early measured vital signs might be limited for the pre-hospital clinical assessment in the motorsport environment. Also, an adjustment of general trauma triage protocols might be considered for settings such as racetracks. Using the context with medical professionals at the victim's side within a few minutes after an accident, that is common in motorsport, offers unique possibilities to increase our understanding of clinical signs and trauma in the early state after an accident.

KEY POINTS
Except for a decreased level of consciousness, this study indicates that the clinical value of early measured vital signs to determine the severity of injuries after road racing crashes on racetracks might be limited.

Type of crash seems to be more significant than speed as indicators for severe injuries on motorcycle crashes at racetracks.

Study settings with medical professionals at the victim's side within a few minutes after an accident offers unique possibilities to increase our understanding of clinical signs and trauma.

BACKGROUND
In 2016, 1.35 million persons globally were killed in road traffic deaths. Of these, about 28% were motorcycle riders [1]. In Sweden, 47 motorcyclists were killed and over 200 were injured during 2018 [2]. Road racing is a motorsport where motorcycles race on paved road surfaces, most often on a racetrack. However, little is known on the prevalence and outcome of accidents from road racing track accidents. One study on crashed in road racing grand prix indicates that 12–14% of all riders suffered a crash during racing [3]. In accordance with road racing regulations, medical teams are often present at racetracks to ensure an immediate emergency response in case of a crash [4]. In such situations, the first professional medical assessment can be made within a few minutes; this is opposed to motorcycle crashes on public roads, where the first public ambulance might arrive significantly later [5].

Prehospital assessment of trauma patients is a crucial part of the trauma care chain [6]. Most

> **"THIS STUDY AIMED TO DESCRIBE VITAL SIGNS OF RIDERS AFTER CRASHES"**

prehospital assessment protocols use a combination of vital signs, detection of certain anatomic injuries, injury mechanism and (sometimes) age [5]. However, little is known about vital and clinical signs in the very early stage after an accident, due to lack of studies and data. Kinetic energy is related to the square of the velocity of a moving object. On racing tracks, speeds may be in the range of 200 km/h, with riders having corresponding extreme energy levels. To address this, protection measures, including safety zones and air fences (inflatable air barriers that protect bikers from hitting a solid fence), are designed to gradually reduce speed and thus energy. Moreover, requirements for wearing personal protective gear, such as helmets, have been introduced to minimize serious injuries [7, 8]. These aspects might affect the clinical assessment of road racing riders. By describing and analysing vital and clinical signs within a few minutes of an accident, a greater understanding of their value for the prehospital clinical assessment in the early state after an accident can be obtained.

This study aimed to describe the vital and clinical signs of motorcycle riders shortly after racetrack crashes and examine the clinical value of these data for prehospital clinical assessments.

METHODS
A retrospective observational cohort study was conducted by analysing medical records from 104 motorcycle crashes on a Swedish racetrack during the road racing season of 2019.

STUDY SETTING
The racetrack used in this study was a permanent racetrack in Sweden. The medical teams consisted of nurses and physicians with experience in prehospital trauma care. In order to drive a motorcycle at the racing track, personal protective gear, such as a helmet and back protectors, was required.

PARTICIPANTS
Data from all motorcycle crashes on the racetrack during the season of 2019 (May 01 until September 17)—when a medical team was present, and therefore, a medical record existed—were included. Crashes from races (national championships and regional/ local competitions) as well as practice runs were included. No private or commercial testing activities occurred on the actual racetrack during the season.

DATA COLLECTION PROCEDURE
Data were collected retrospectively from paper medical records taken at the racetrack. Information on vital signs, clinical injury signs, type of crash and speed at crash was collected from the paper records and imported to the statistical programme SPSS (IBM Corp., released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). Three types of crashes [7] were studied: lowsider crashes, or crashes resulting from a loss of traction,

where the motorcycle went down on the side closer to the ground; highsider crashes, involving sudden and violent long bike axis rotations, where the bike was oversteered into a turnover; and collisions with other bikers. If the riders were unable to specify actual speeds for their crashes, an estimation based on the specific location around the racetrack was used. For this purpose, time-tracking systems and helmet cameras providing speed measurements from ten professional and semi-professional motorcycle riders were used to determine the mean speed at all locations around the racetrack.

All vital signs were measured by members of the medical team. Clinical signs of injury were defined as documented pain or observed obvious injuries, such as paradoxical breathing, extremity deformities or external bleeding. For patients referred to an emergency hospital, information on their condition (measured with injury severity score (ISS) [9] and new injury severity score (NISS) [9]), documented type of injuries and status at discharge from hospital was collected from the Swedish Trauma Registry (SweTrau) and integrated into the SPSS dataset.

In order to ensure that all serious accidents at the racetrack during the observed season were included, the Nordic Motorsport Council and the insurance company that covers licensed racing motorcyclists were contacted and asked if they had any knowledge of reported injuries or fatalities of motorcycle drivers due to crashes at that specific racetrack aside from those already included. In addition, public ambulance alarm records for the racetrack were also scanned for accidents not included in the current data.

ANALYSIS

For descriptive analysis, percent proportions and, when applicable, means, ranges, standard deviations (SD) and a 95% confidence interval (CI) were used to describe participant demographics, injuries and other information. Due to a small study sample and outliers, the Kruskal-Wallis test was used to analyse any differences between vital sign means among uninjured, injured and severely injured riders. Bonferroni post hoc analysis was used to determine significant differences between groups. Multiple regression analyses were conducted to calculate the association of speed at crash, type of crash, age of the rider, occurrence of clinical signs of injury and abnormal first vital signs (GCS, RR, Sp02, HR and SBP) measured within the first 10 min from the crash (n=62) with the occurrence of injuries (dependent variable). The exact analysis used and outcome variables are presented in each table or in the results. Injuries were defined as any signs of injury documented in the medical records or recorded, based on ISS, in the SweTrau. Mild injuries were defined as those with an ISS of 1–14, and severe injuries were defined as those with an ISS > 15 [7]. A confidence interval of 95% and a statistical significance of $p \leq 0.005$ were used with regard to the limited observations included [10]. No post hoc test was conducted, but the statistical analysis was verified by an external statistician.

> **“THE FIRST VITAL SIGNS WERE REPORTED BETWEEN TWO AND 58 MINUTES AFTER A CRASH”**

Ethical approval was obtained from the Swedish Ethical Review Authority (dnr 2019-05803).

RESULTS

Data from 104 motorcycle crashes were analysed. The gender distribution was 97 (93%) males and 7 (7%) females with ages ranging between 14 and 64 years (mean 38 years, SD 14). Of the crashes, 42 (40%) occurred during racing and 62 (60%) occurred during practice runs. Lowsider crashes represented 67 (68%) accidents, highsider crashes accounted for 20 (20%) accidents and 12 (12%) were caused by collisions with other motorcycles (data were missing for five crashes). Crash speeds (actual speed stated by the rider n= 80, or estimated speed n=24) varied from 50 km/h to over 180 km/h, with a mean of 92 km/h (SD 24).

In all, 30 riders (29%) were considered injured. Of these, 25 patients (24%) had suffered injuries (ISS 1–14) and 5 (5%) sustained major trauma (ISS > 15). Sixteen riders were referred to the hospital as trauma patients. The mean ISS for those 16 patients was 8 (range 1–21; SD 6) and the mean NISS was 10 (range 1–29; SD 8.1). Five riders (5%) were classified as having major trauma (ISS > 15) (see Table 1). None were reported dead after 30 days. Neither the motorcycle or insurance organizations nor the public local ambulance services had knowledge of any accidents on the racetrack that were not already part of the data.

The first documented vital signs were reported between 2 and 58 min after crashes, with a mean of 15 min (SD 18). In 35 (34%) of the accidents, vital signs were reported within 3 min of the crash. After 5 min, 47 accidents (45%) had vital signs measured, and 78 cases (75%) were accounted for within 10 min of the crash. Just nine accidents (8%) had initial vital signs measured after 60 min (see Fig. 1).

VITAL SIGNS WITHIN THE FIRST MINUTES AFTER AN ACCIDENT

The vital signs observed within the first minutes after a crash varied considerably. The first measured heart rates for all riders and the times for those observations are displayed in Fig. 1. As shown, heart rates varied between 67 and 146 beats per minute (mean 105; SD 18). When comparing the first measured heart rates among seriously injured (marked in Fig. 2) and uninjured riders, no significant difference could be observed (Fisher's exact test; uninjured riders: n = 67; M = 104; SD = 18; injured riders: n = 28; M = 105; SD = 18; 95% CI −7 to 9, p = 0.92).

The means of vital signs among uninjured, injured and seriously injured riders were compared using the Kruskal-Wallis test (see Table 2). A significantly lower Glasgow Coma Scale (GCS) was observed when comparing both uninjured (15; SD 0) with injured riders (12; SD 4) (Kruskal-Wallis test: H (2) = 19; p = 0.00; post hoc Bonferroni adjusted; $p \leq 0.00$) and uninjured (15; SD 0) with seriously injured riders (13; SD 2) (Kruskal-Wallis test: H (2) = 19; p = 0.00; post hoc Bonferroni adjusted; $p \leq 0.00$). An increased respiratory rate among seriously injured

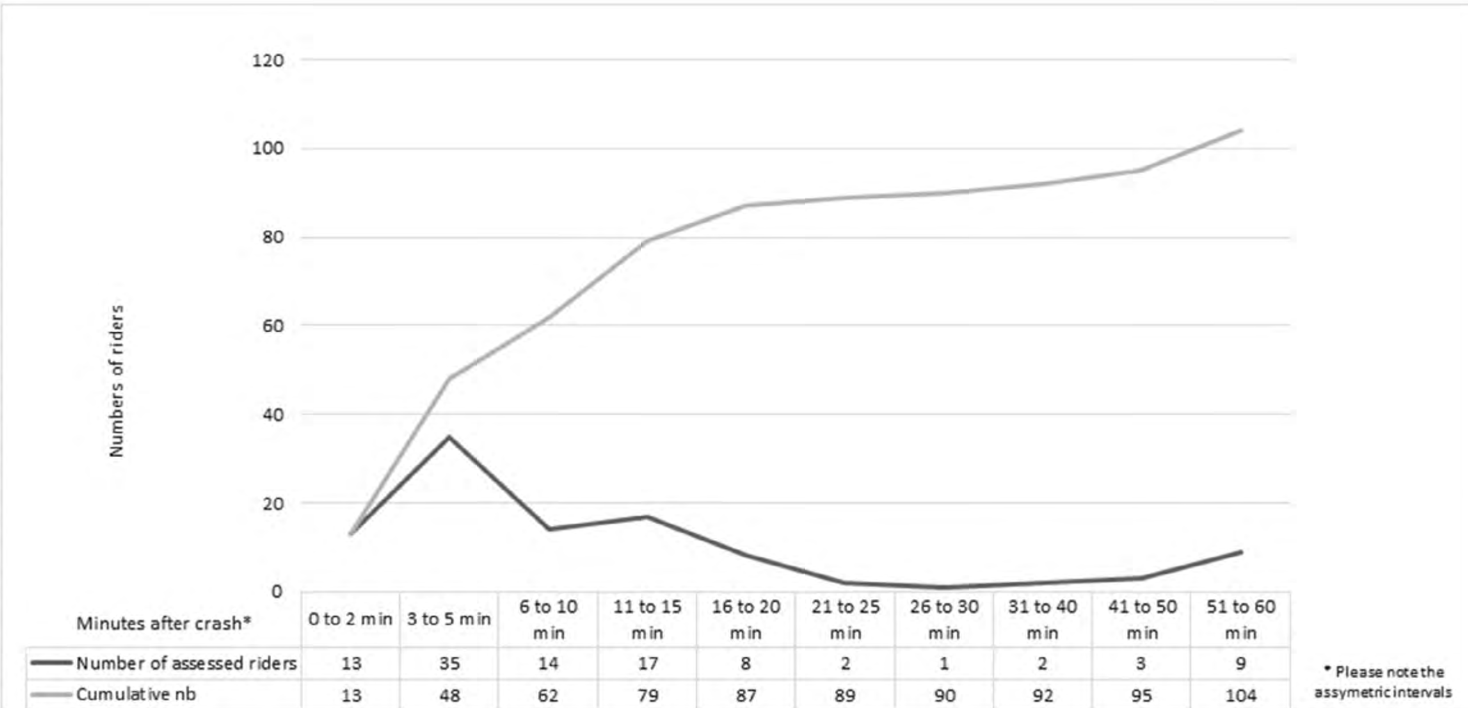
Table 1 Overview of outcomes for all riders

Outcome, *N*=104	***n* (%)**
Considered injured	30 (29)
Transported from track to racetrack medical centre with ambulance*	35 (34)
Attended the racetrack medical centre by feet*	69 (66)
Cleared on the track and returned to paddock or race	79 (76)
Referred to hospital as trauma patients	16 (15)
Advised to seek to non-emergency medical care	9 (9)
Reported dead after 30 days	0 (0)

*In accordance with regulations, all riders who crashed had to visit the medical centre after the crash in order to get medical clearance

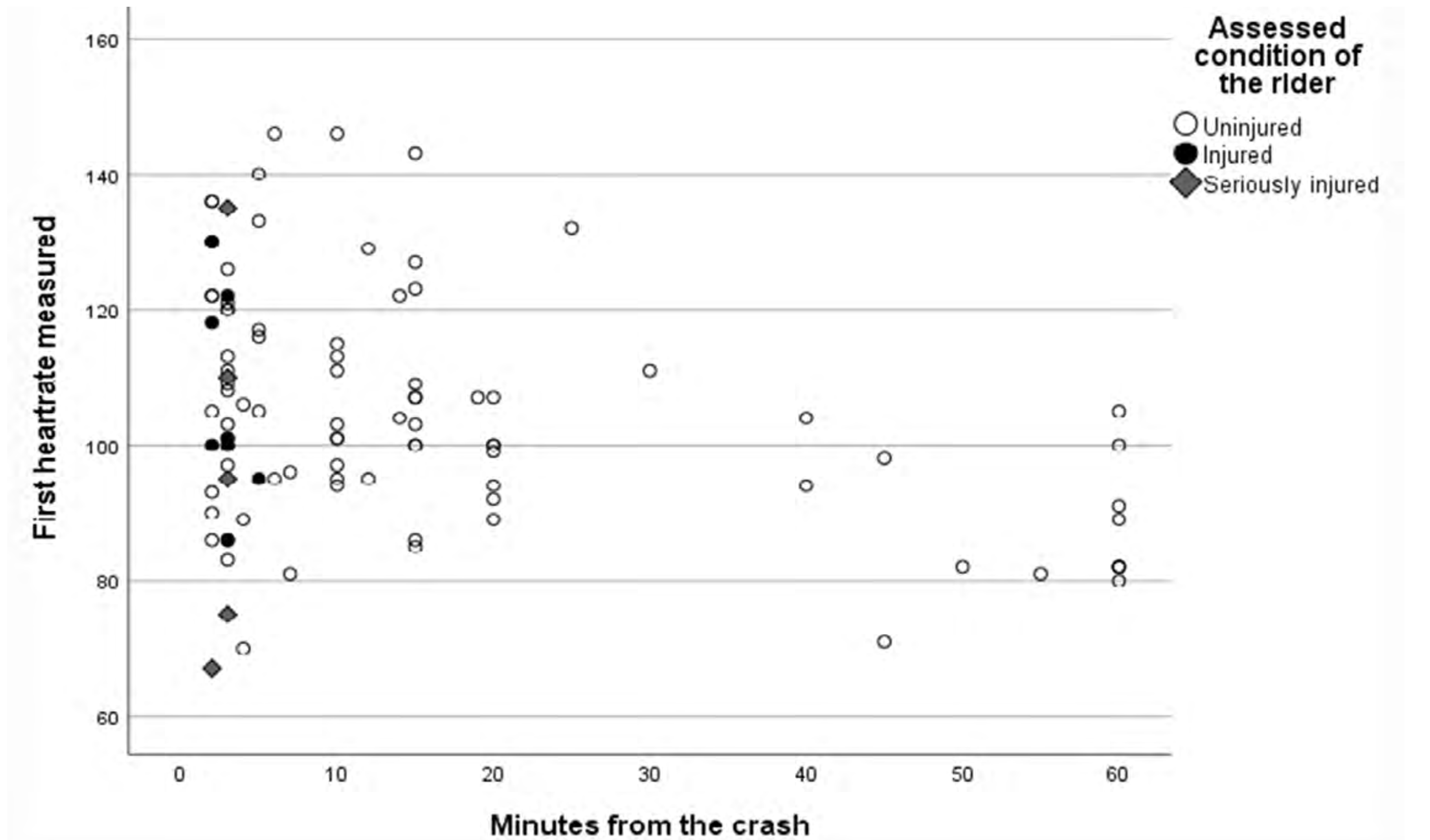
AUTO+MEDICAL SCIENCE

Figure 1 Overview of time for first documented vital signs



Minutes after crash*	0 to 2 min	3 to 5 min	6 to 10 min	11 to 15 min	16 to 20 min	21 to 25 min	26 to 30 min	31 to 40 min	41 to 50 min	51 to 60 min
Number of assessed riders	13	35	14	17	8	2	1	2	3	9
Cumulative nb	13	48	62	79	87	89	90	92	95	104

Figure 2 First measured heart rates and times after accidents



(mean 25; SD 6) compared to uninjured (mean 18; SD 2) riders was also observed (Kruskal-Wallis test: H (2) = 7.6; p = 0.22; post hoc Bonferroni adjusted; p = 0.02). No other vital signs were significantly different between the groups.

The development of vital signs for seriously injured patients during the first 15 min after an accident is shown in Table 3. Despite abnormal signs (as defined by the Swedish Trauma Protocol) in the very early phases, most vital signs were normalized when patients arrived at the hospital (see Table 3).

PREHOSPITAL CLINICAL SIGNS OF INJURIES

Of all 104 riders who crashed, 74 (71%) had no signs of injury at all, while 30 (29%) were considered as injured. The injury location was six (20 %) suffering from head injury, seven (23 %) with upper extremity injuries (i.e. arm, hand or shoulder), 10 (33 %) with lower extremity damage (i.e. leg or foot), five (17 %) with thoracic injuries and two (6 %) suffering from suspected spinal cord injury. When comparing prehospital and hospital assessments of injury locations, there was a 75% match for the 16 patients transferred to the hospital. Five of the patients (31%) had additional injuries identified by the hospital trauma team as compared to the documented prehospital assessment. These included fractures or soft tissue injured on more locations than identified prehospital. None of the additional injuries found were considered as life threatening or severe on their own but added severity to the overall condition of the injured rider.

ASSOCIATION BETWEEN TRAUMA MECHANISMS, VITAL SIGNS MEASURED EARLY AND INJURIES

The occurrence of injuries was associated with highsider or collision crashes, a prehospital decreased level of consciousness (GCS < 15) and clinical signs of injuries; the type of crash had the greatest impact (see Table 4).

DROPOUTS

A few patients had incomplete vital sign documentation in any or several readings (heart rate (n=3), breathing frequency (n=2), systolic blood pressure (n=3)) and three (n=3) had no documented SpO2 assessments but all other data. No specific dropout analysis was conducted due to the small number of participants.

DISCUSSION

This study has shown that about 30% of all road racing crashes on the racetrack during practice and racing caused injuries, and in 5% of these, the riders were severely injured. Vital signs in the early phases after crashes varied significantly. Aside from a decreased level of consciousness, no single vital sign or kinematic component observed shortly after a crash was a strong indicator of neither injuries nor severe injuries. However, weak links may exist between highsider or collision crashes and the occurrence of injuries.

A decreased level of consciousness was more common among injured or severely injured riders compared with uninjured riders and was associated with the occurrence of injuries in the regression analysis. The results showed that the injured group had a lower mean GCS that the serious injured group. Also, it should be noted that two riders had normal GCS both at the racetrack and when arriving to hospital but were still severely injured. None of these two was diagnosed with traumatic brain injury. Since the number of injured among these subgroups were small, no conclusions can be drawn from these differences. The GCS has been found to show strong agreement when prehospital assessments were compared with emergency department assessments [11]. However, the patients in this study who presented a prehospital lowered level of consciousness showed normal levels when arriving at the hospital. It should be noted that in this study, medical professionals reached the patients within minutes of their crashes and could make professional assessments of consciousness levels. Normally, when ambulances arrive awhile after accidents, assessments of early decreased consciousness must rely on information gathered from bystanders or patients themselves. Such information may be less reliable or unavailable, depending on the circumstances. The current findings might be due to the presence of medical professionals, or from the very early clinical assessment made. The use of vital signs in prehospital assessments of trauma patients has been questioned [12, 13]. Within a few minutes of high-speed motorcycle crashes, vital sign variation was considerable. Some uninjured riders had heart rates over 120 during the first minutes without being seriously injured, while others had normal vital signs but were severely injured. One reason for this finding may be the physical demands of road racing, which make it difficult to distinguish between pathological high heart or respiratory rates shortly after a crash, or the physical fitness of the riders. Vital signs among the severely injured riders showed some abnormal values but also considerable variation during the first 15 min. Since clinical decision-making in the prehospital context is a complex process [14] where each patient must be examined thoroughly to avoid any misinterpretation of conditions [6, 14] repeated observations and trends over time may be more reliable and of greater clinical value than single measurements for predicting injury severity in a very early phase. This study could not confirm if vital signs measured later were more reliable as indicators of injury severity than vital signs measured early. Neither the observed mismatch of injury location nor the clinical effects of this mismatch could be concluded from the available data. However, the results indicate that timing and context must also be considered in such assessments. This is important to consider for medical teams on standby in high-risk sports.

According to the Swedish trauma team's activation protocol, crash speeds over 35 km/h require trauma team activation for motorcycle accidents [15]. In this study, crashes occurred at actual or estimated speeds from 50 to 180 km/h, but no association was found between speed and the occurrence of injuries. However, 23% of the speed data in this study relied on estimated speeds. The estimations were based on professional or semi-professional riders and might therefore not be representative for nonprofessional riders. Despite these limitations, the findings indicate that crash speeds may not be a good indicator to previse the severity of motorcycle injury on racetracks. By contrast, the results suggest that highsider and collision crashes could be a better indicator in these settings; this was also observed by Bedolla et al. [6]. An adjustment of general trauma triage protocols could therefore be considered for specific contexts such as racetrack accidents, in order to provide guidance on prehospital trauma triage.

There are significant differences between racetracks and public roads. At racetracks, bikers are often experienced and trained, having safety zones and mandatory personal protection gear that gradually dissipates energy in case of a crash. Motorbikes on public roads must share the road with other types of vehicles, some travelling in the opposite direction. Moreover, public bikers have the choice of going without protective gear. Another difference is that professional or semi-professional riders most often are elite athletics. Therefore, generalizing these findings to public motorcycling should be done with caution. The low rate of serious injuries despite extremely high speeds could indicate that the protective measures on racetracks are effective in reducing the risk of severe injuries compared with public roads. Regardless, crashes at racetracks offer a special opportunity to collect early crash data and may provide valuable insights into motorcycle crashes and prehospital clinical assessments that could benefit the larger, non-competitive motorcycle riding population [6, 16]. The study's setting, where medical professionals were able to respond within minutes of an accident, offers knowledge that cannot be obtained easily in ordinary prehospital trauma care or registers. Similar settings are available in other sports, such as alpine skiing. Using data from these settings offers a unique possibility to further understand the initial timeframe after accidents. Therefore, this study has value despite the limited number of crashes included. The results of this study raise several questions concerning prehospital clinical assessment of trauma patients. Further research should be undertaken to investigate the development over time of vital signs in trauma patients and further discuss their value for

Table 2 Vital signs measured within the first 5 min among uninjured, injured and seriously injured riders

Vital sign	*n*	Uninjured Mean (range, SD) (95% CI)	Injured Mean (range, SD) (95% CI)	Seriously injured Mean (range, SD) (95% CI)	*p*-value*
Heart rate	44	109 (70–140, SD 17) (95% CI 102–116)	107 (86–130, SD 16) (95% CI 92–102)	102 (67–135, SD 28) (95% CI 56–147)	0.34
Respiratory rate	40	18 (16–22, SD 2) (95% CI 17–18)	18 (16–22, SD 2) (95% CI 16–21)	25 (18–32, SD 6) (95% CI 18–25)	0.02**
SpO2	46	96 (94–98, SD 1) (95% CI 95–96)	95 (92–98, SD 2) (95% CI 93–97)	94 (90–97, SD 3) (95% CI 90–99)	0.82
Systolic blood pressure	43	139 (104–189, SD 20) (95% CI 131–147)	141 (105–190, SD 32) (95% CI 112–171)	133 (112–163, SD 23) (95% CI 96–170	0.08
GCS	48	15 (15–15, SD 0) (95% CI 15–15)	12 (3–15, SD 4) (95% CI 11–15)	13 (12–15, SD 2) (95% CI 11–16)	< 0.00**

SpO2, peripheral capillary oxygen saturation; *SBT*, systolic blood pressure; *GCS* Glasgow Coma Scale
*Analysed with the Kruskal-Wallis test. **For significant results, post hoc tests using Bonferroni were made to compare pairs within the groups (see text)

Table 3 Overview of seriously injured riders' vital signs during the first 15 min after a crash

			Minute 1 to 5 after crash					Minute 6 to 10 after crash					Minute 11 to 15 after crash					At arrival to hospital				
Patient	Speed (km/h)	Age	HR	BF	Sp02	GCS	SBP	HR	BF	Sp02	GCS	SBT	HR	BF	Sp02	GCS	SBT	HR	BF	Sp02	GCS	SBT
A	180	53	75	n.a	95	12	n.a	75	14	95	13	n.a	81	16	96	15	n.a	76	18	97	15	175
B	75	32	95	32	95	15	112	88	30	97	15	108	88	26	96	15	110	90	25	98	15	115
C	75	63	67	22	90	12	117	60	22	98	15	73	50	20	99	15	87	76	20	96	15	95
D	180	50	110	18	95	15	140	100	16	96	15	130	n.a	n.a	n.a	n.a	n.a	105	18	95	15	140
E	120	35	135	29	95	12	163	100	18	96	15	150	n.a	n.a	n.a	n.a	n.a	97	20	97	15	140

HR= heart rate, BF= breathing frequency, SpO2= peripheral capillary oxygen saturation, CGS = Glasgow Coma Scale, SBT= systolic blood pressure
n.a = information not available. Grey marking = abnormal vital sign according to the Swedish trauma team's activation protocol.

HR, heart rate; *BF*, breathing frequency; *SpO2*, peripheral capillary oxygen saturation; *GCS*, Glasgow Coma Scale; *SBT*, systolic blood pressure; *n.a*, information not available; grey marking, abnormal vital sign according to the Swedish trauma team's activation protocol

Table 4 Correlation between first measured vital signs within 10 min from the crash, speed, age of rider, type of crash and occurrence of injuries

	B	95% CI	*t*	Sig.
Speed ≥ 90 km/h	0.02	(−0.06; 0.06)	0.56	0.59
Highsider or collision	0.92	(0.00; 0.19)	1.94	*0.05*
Age ≥ 40 years	−0.12	(−0.11; 0.85)	−0.25	0.81
GCS < 15	0.27	(0.74; 0.46)	2.75	*0.00*
Respiratory rate < 10 or > 29	0.15	(−0.14; 0.44)	1.04	0.30
SpO2 < 95%	0.03	(−0.18; 0.25)	0.31	0.76
Heart rate < 50 or > 120	−0.10	(−0.20; −0.00)	−2.24	0.08
SBT< 90	0.13	(−0.03; 0.29)	1.56	0.17
Clinical signs of injury	0.68	(0.57; 0.78)	12.6	*0.00*

Model summary: $p = 0.00$, $R^2 = 0.93$. Outcome variable: injuries

B, unstandardized coefficient beta; *CI*, confidence interval (lower bound; upper bound); *Sig.*, *p* value; cursive number, significant *p* value. *GCS*, Glasgow Coma Scale; *SBT*, systolic blood pressure; *SpO2*, peripheral capillary oxygen saturation

prehospital assessment. Additionally, the value of kinematic data in prehospital trauma triage protocols for different settings and activities needs to be further explored.

LIMITATIONS

The study has several limitations. First, the number of severely injured patients in this study sample was very small, reducing the possibility of generalizing the results. However, this is also a finding itself, that fewer serious injuries than expected occurred at the racetrack. The available data only cover accidents that occurred on a racetrack when medical professionals were on standby. Despite regulations, it cannot be excluded that any road racing activities were conducted without the medical team on standby, and therefore not covered in this study. In addition, there may have been late complications or injuries requiring medical care that were not covered in this study—for example, if the patient had sought medical care in another country (e.g. their home country). However, the screening of insurance companies, motorcycle organizations and public ambulance services showed that they had no information on fatalities due to accidents on racetracks during the period studied. The SweTrau register reports both ISS and NISS for each incident. As the ISS and NISS have been reported to have a similar ability of predicting mortality in trauma patients [17], this study used the ISS only to define severe injuries in the analysis.

CONCLUSIONS

Vital signs measured within a few minutes of riders being involved in motorcycle crashes on a racetrack varied considerably. Except for a decreased level of consciousness, the clinical value for prehospital assessment of vital or clinical signs measured early might, therefore, be limited. The type of crash seemed to be a better indicator of severe injuries than estimated speed at crash, and it could be considered to adapt general trauma triage protocols to the racetrack settings. Using the context of a study setting with medical professionals at the victim's side within a few minutes after an accident offers unique possibilities to increase our understanding of clinical assessment in the very early state after an accident. Therefore, such study settings may benefit both sports medicine contexts and general trauma care.

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ABBREVIATIONS

BF: Breathing frequency
CI:Confidence interval
GCS: Glasgow Coma Scale
HR:Heart rate
ISS: Injury severity score
NISS: New injury severity score
SpO2: Peripheral capillary oxygen saturation
SD: Standard deviations
SweTrau: Swedish Trauma Registry
SBT: Systolic blood pressure

AVAILABILITY OF DATA AND MATERIALS

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

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