

# Men and women aren't equal when it comes to concussion

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Women athletes are twice as likely as men to get concussed—and the effects are more severe. But with research focusing mainly on men, what can we do to make sure women with concussion aren't left behind?

Few sports are as fast and furious as roller derby. The hour-long game unfolds in frenetic two-minute bursts as two teams race anti-clockwise around an oval track.

Each team has a "jammer" aiming to pass four opposing "blockers," and they score points for each opponent they lap.

Blockers can obstruct the path with their torso or push opponents off course with a swift nudge of their upper legs or upper arms. Jammers "juke"—a sideways dummy move—and "whip"—where a team member grabs their hand and swing them forwards ahead of the pack.

Fans are addicted to the ferocious drama of the competition, but, as you would expect for any contact sport, injuries are commonplace.

Jessica had just moved to the U.S. from France when she attended her first roller derby match. "From that first game I really fell in love with it," she says. She started competing, eventually leading Team France in the 2011 World Cup, and she even met her wife through the game.

In the summer of 2016, Jessica was playing blocker for a team in the Bay Area, California. She was in front of the opposition's jammer, and

just as she turned to check her position, an opposing blocker collided with her at high speed.

As the blocker's shoulder hit the right side of her chin, Jessica felt an extraordinary pain on the opposite side of her skull and fell to the floor. The sudden jerking movement of her head, she now knows, caused her brain to ricochet within the skull—leading to the sharp pain and severe [concussion](#).

She didn't seek immediate medical care. When she had suffered concussion previously, her doctor's advice was to take it easy for a few weeks before returning to play. And it had seemed to work fine.

This time, however, she had continued headaches and sense of mental constriction—a feeling of pressure, like a "vice" on the brain, she says—no matter how much she rested. Concentration for any length of time was often extremely difficult, and she was sensitive to the bright light of computer and phone screens, meaning that she had to wear sunglasses at work.

She also experienced inexplicable dips in her mood; at work, she would sometimes have to go and cry in her car. "There was nothing that would have prompted it," she says. "And I was not somebody who cried very easily, so it was exceedingly alarming for me to suddenly have these bursts of tears happen from nowhere."

It is now three years since her injury, but Jessica still hasn't recovered fully from these symptoms. "I haven't given up hope, but at this point, it's not like there's a clear path to being better, or a clear timeline of when that would be."

Could Jessica have been at a higher risk of concussion simply because of her sex? Compelling new research suggests this is a distinct possibility,

with a growing recognition that male and female brains may respond to injuries very differently.

This follows a wider growing concern about concussion, triggered, in part, by high-profile injuries in sports like soccer, American football, rugby and boxing.

Concussion is changed neurological function as the result of a bump, blow or jolt to the head. The violent movement of the head causes a momentary release of various neurotransmitters that throws the brain's signalling out of balance. It can also cause the neural tissue to swell and reduce the flow of blood to the brain—and along with it, the glucose and oxygen—starving our nerve cells of their fuel.

Immediate symptoms include seeing stars, feeling dizzy and confused, or losing consciousness entirely. Many people also suffer from post-concussion syndrome long after the event, with a constellation of lingering symptoms, including nausea, headaches, dizziness and mental confusion. These can last for weeks, months or even years. Some studies suggest that a concussion may also be accompanied by an increased risk of suicidal thinking, and there are concerns that repeated injuries could lead to long-term damage and brain degeneration.

The potential long-term impact of concussion is now well-known and has led many sports associations to change their rules and procedures to reduce the danger of injury. But there is low awareness of the potentially higher risks to female players and the possible need for differing diagnosis and treatment, including among healthcare professionals. "At no point at any time when I was talking to physicians did they ever mention any potential difference [arising] from being a woman," says Jessica.

Recent research, however, suggests that [female athletes](#) are not only

more likely to sustain a concussion in any given sport; they also tend to have more severe symptoms, and to take longer to recover.

Katherine Snedaker, founder of the non-profit campaign group Pink Concussions, believes that many like Jessica are "invisible patients" with an "invisible injury"—and that means that they may struggle to get the support they need.

By shining a light on these differences, and understanding their causes, scientists and campaigners like Snedaker hope to improve the plight of all women struggling with the lingering and sometimes debilitating consequences that can arise from a single blow to the head.

Given that millions of people a year sustain concussion around the world, and many more women are now taking up contact sports like rugby and soccer that might put them at greater risk of injury, this new understanding cannot come soon enough.

Concussion is thought to have first been distinguished from other types of brain injury more than 1,000 years ago, by the Persian physician Rhazes, but sex differences in concussion have only been the subject of serious research within the last two decades or so.

The delay perhaps reflects a historic sexism within medicine, which has often neglected to investigate the possibility that female bodies may act differently from male bodies (besides the obvious differences, for example, in reproductive health). In the past, most clinical trials had included many more men than women, for instance—though that has now improved. Most animal trials were also conducted on males, and it was only in 2014 that the US National Institutes of Health announced that studies it funded must use female as well as male animals, unless there were clear reasons to focus on one and not the other.

The sex differences in concussion were also obscured by the fact that many of these injuries are the result of accidents in sport, and girls and women were historically less likely to compete in events where concussion has attracted most attention.

Tracey Covassin, who is now based at Michigan State University, has been one of the leading researchers looking at potential sex differences in concussion. Canadian by birth, and inspired by her own love of ice hockey, when she first started out 20 years ago, she found next to no research on the subject.

"There was nothing that really looked at females and concussion, because everything was about the NFL or the NHL, and concussions in male athletes or boxers."

To correct that deficit, Covassin turned first to the National Collegiate Athletic Association's injury records, to see how common concussion was among males and females within the same sports. In soccer, basketball and softball, for example, she found that female players are almost twice as likely to suffer a concussion as male ones.

Covassin and others then began to look at the effects of a concussion. They found that males and females are also likely to report different symptoms in the following days and weeks.

While male concussions are more likely to be followed by amnesia, for instance, female ones are more likely to lead to prolonged headaches, mental fatigue and difficulties with concentration, and mood changes.

Female athletes also seem to require more time for those symptoms to disappear. One study of 266 adolescents—including soccer and American football players, wrestlers and skiers—found that, on average, females took 76 days to recover, while males took 50 days.

As Esther, a student at Georgetown University in Washington, DC, who had a debilitating concussion while playing soccer when she was in the eighth grade, tells me: "I just didn't really realise how serious it was. And then it wasn't really until the following day, when I returned to school as normal, that I couldn't really see the whiteboard. I felt so nauseous and had a horrible, horrible headache."

The symptoms lingered. Even at lunchtime, she says, it was a struggle to concentrate on what others were saying in the noise of the room, and watching a documentary in class gave her waves of nausea. Her post-concussion syndrome lasted for two and a half years, but, just as she was beginning to feel back on track, she suffered a new concussion (from falling down a flight of stairs) that led to further prolonged symptoms that she's still learning to cope with today, four years later. "I think the symptoms that I still have now are kind of a cumulative effect."

Anna, an 18-year-old from New York City, sustained three concussions while playing basketball during her second and third years of high school. The third concussion was the most debilitating, resulting in her taking four to five months off school to recover.

"I had terrible headaches, I wasn't able to properly think or put sentences together in a logical manner," she recalls.

Some researchers have argued that many of the reported sex differences are simply the result of societal gender roles.

Maybe girls and women are more cautious about their health, and more likely to disclose symptoms, while boys and men have been conditioned to "play through the pain"? Evidence to support some kind of baseline difference in the self-reporting of symptoms is mixed, however.

Some studies have also used more objective measures of cognitive

function, with one finding females were about 1.7 times as likely as males to show signs of cognitive impairment a few days after experiencing the concussion. This includes a much larger decline in reaction times. Concussed female athletes also tend to show greater deficits in visual memory (though not every study has been able to detect this difference).

Given this evidence, self-reporting "cannot be the only reason" for the sex differences, says Inga Koerte, a neurobiologist at Harvard Medical School and the Ludwig Maximilian University of Munich.

Following a concussion, female athletes also seem to perform worse than males on a test of the vestibular-ocular reflex—which allows our eyes to fix on a target as our body moves.

These tests ask people to focus on a fixed point as they move their head up and down or side to side and then rate symptoms of headache, dizziness, nausea or feelings of "fogginess." The close observation makes it hard for someone to hide their condition, says Covassin. "So even if they're trying to lie to you about it, they just don't look very good," she says. That should reduce any self-reporting bias, yet in this test females are still found to have worse symptoms than males.

Perhaps the assumption that boys and men are somehow more ambitious and competitive—and therefore more likely to hide their symptoms—is itself a reflection of some outdated stereotypes and implicit biases?

Snedaker thinks so. "I think that women's pain has been discounted—as it has been for other mental or other physical injuries."

She points to some evidence that women, in general, are less likely to be prescribed painkillers in hospital. A 2008 study of American patients undergoing cardiac surgery, for instance found that women were more



likely to be given sedatives than men, who were more likely to be given painkillers—perhaps because doctors implicitly assume that women's distress is more emotional than physiological. Another study found that women reporting to the emergency room with abdominal pain were less likely to be prescribed painkillers than men with the same complaint.

Ramesh Raghupathi, a professor in neurobiology and anatomy at Drexel University in Philadelphia, is similarly sceptical of the idea that we can dismiss the sex differences in concussion so easily.

He says that he has come across many female athletes who play through their pain rather than give up on their sporting ambitions—despite the risks that this involves. "Especially at [high] levels of competition, girls at middle school, high school or college—they're just as likely to hide their injuries," he says.

In the weeks before Jessica's concussion, she had sustained some minor impacts, but had chosen to return to play—which may then have exacerbated the effects of the later injury. In hindsight, she now wishes she had taken more time out.

Understanding exactly why women are more susceptible to concussion will be essential, if we are to reduce those risks. Recent research has focused on three main theories.

Some researchers have proposed that it may be due to the fact that female necks tend to be slimmer and less muscular than male ones.

Remember that the brain is free to move within the skull—it is like jelly tightly packed into a Tupperware container—and this means that any sharp movement of the head can cause it to shift around, potentially causing damage.



For this reason, anything that helps to protect the skull from sharp movements should protect you from concussion—and that includes a sturdier neck that is better able to buffer a blow.

"If you have a thicker neck, you have a stronger base, so the likelihood of head movement is much less," says Raghupathi.

Overall, the girth of a female neck is about 30 percent smaller than a male, and this increases the potential acceleration of the head by as much as 50 percent, according to one study.

The second idea that researchers have pointed to is some small anatomical differences within the brain itself. Female brains are thought to have slightly faster metabolisms than male ones, with greater blood flow to the head: essentially, they are slightly hungrier. And if a head injury momentarily disrupts that supply of glucose and oxygen, it could cause greater damage.

The third possibility lies in female sex hormones—with some striking evidence that the risk of concussion changes with varying hormone levels during the menstrual cycle.

Researchers at the University of Rochester School of Medicine and Dentistry, for instance, tracked the progress of 144 concussed women visiting six emergency departments in upstate New York and Pennsylvania.

They found that injuries during the follicular phase (after menstruation and before ovulation) were less likely to lead to symptoms a month later, while an injury during the luteal phase (after ovulation and before menstruation) resulted in significantly worse outcomes.

Exactly why this may be is still unclear, but it could relate to the rise and

fall of progesterone levels during the cycle phases.

Previous research has shown that head injuries can temporarily disrupt the production of various hormones, including progesterone. During the luteal phase progesterone levels are highest, and the researchers hypothesise that the sudden "withdrawal" due to head injury throws the brain off balance and contributes to the worse lingering symptoms. In the follicular phase, by contrast, progesterone levels are already lower and would not drop so dramatically—meaning the resultant symptoms are less severe.

In line with this hypothesis, various studies have found that females taking contraceptive pills are also less likely to suffer severe symptoms following a concussion. Amy Herrold at Northwestern University's Feinberg School of Medicine, in Chicago, explains that oral contraceptives work by regulating the levels of sex hormones in the body. "So instead of having hormonal surges and dips, over the course of a month, it's more consistent," says Herrold, who also works as a research scientist at the Edward Hines, Jr. VA Hospital in Illinois.

Provided that the pill continues to be taken after the concussion, that could prevent the sudden fall in progesterone, which would explain the less severe symptoms.

Complicating matters, the surges in oestrogen and progesterone during the luteal phase might also influence dopamine signalling. Dopamine is implicated in many of the brain's functions that are influenced by concussion—including motivation, mood, memory and concentration—making it a good contender for a potential mechanism.

Raghupathi's team's recent work on animals suggests that the surge of hormones during the luteal phase could render dopamine receptors slightly more vulnerable to perturbation. So, if a head injury occurs

during this time, it seems to throw the dopamine signalling off balance in the long term, with potentially important ramifications for those many different brain functions. "It's the disruption of this connectivity between cells [and] between regions that is a potential basis for the behavioural problems," Raghupathi says.

But, as Tracey Covassin emphasises, we still don't know how much truth these hypotheses hold. "I wouldn't say any of them are clearly determined at this point."

The different explanations aren't mutually exclusive: further research may find that the differences in musculature, blood flow, and the balance of hormones and neurotransmitters all contribute.

Future research will also have to investigate other longer-term consequences of concussion. There are concerns, for example, that head impacts can increase the risk of neurodegenerative diseases like Alzheimer's. We don't know if women may be at a greater risk here too.

Although the evidence for these sex differences has grown over the last few years, some experts would prefer to see these results replicated with further, carefully controlled studies, before the message is widely shared.

Without that corroboration, they worry that inadequately supported public claims may inadvertently harm women's recoveries. As Melissa McCradden, a neuroscientist and former competitive athlete, argued in a piece for Scientific American in 2017, a patient's own expectations can influence their progress. "So if we label women in this way, it can have a direct, negative effect on their recovery from concussion," she wrote.

There is also the fear that this information might put males at greater risk, if they wrongly assume that concussion is only a female problem.

"If you focus too much on any kind of perceived or possible male-female divide, it might give this false perception that actually males are more able to withstand concussion [than they really are]," says Luke Griggs, the deputy CEO of Headway, a charity that offers support for the survivors of brain injury and their carers across the UK. Boys and men might believe they could return to play too early—whereas everyone, he emphasises, should be cautious following a concussion rather than trying to ignore their symptoms.

These are reasonable concerns, but many with concussion have been frustrated by the current lack of awareness about their condition.

Esther told me that some of her doctors were aware of the sex differences. But she would have preferred to know herself, before she ever got concussed. "I had no idea," she says. "And I think that if you're an athlete, playing any sport, you deserve to know the potential risks. If you're a girl playing sports, you deserve to know that maybe you are more at risk than your male counterparts."

Esther and Jessica emphasise that they wouldn't have let the risks prevent them from playing the sports in the first place—this should not be taken as another excuse to limit the potential of girls and women. But they hope that female athletes would benefit from having the knowledge to protect themselves from unnecessary injuries and to ensure that they do not feel pressured to return to play too quickly, for instance.

Better awareness of these sex differences could ultimately lead to better care before and after the event.

One strategy might be to build better headgear for women. Unfortunately, it's not quite that simple: concussions can arise from the sudden movement of the head as well as from a direct blow to the skull, which means that headgear won't prevent certain causes of concussion

(though it can prevent fractures and other head injuries).

Some researchers are taking another approach: designing special exercises which could strengthen female neck muscles, which could reduce the violent movement of the head following an impact. "It could decrease the basic chance for [concussive] brain injuries," says Inga Koerte.

And if further research shows that the sudden drop in progesterone increases the risks, then it might be a reason for female athletes to take oral contraceptives (though the evidence is not yet strong enough to make this recommendation).

For Jessica, these measures will be too late. She now lives and works in the UK, and after three years, many of her symptoms have subsided enough for her to "mostly live my life without too much trauma," she says, but she still has a constant lingering headache, and she has to be on constant watch-out for a "flare-up"—which can occur whenever she has over-exerted herself. And small difficulties that she once could have easily managed continue to feel overwhelming.

Indeed, on the day we were due to speak, she had been making some sales forecasts for work. She says it was hardly "rocket science," yet she soon felt the fog descending.

"I was looking at those numbers, and nothing made sense—like I couldn't [even] figure out where to start to have them make sense."

She is still unable to play her beloved roller derby, and even running—with its repeated jolting movements reverberating through the body—is too much to bear, though she has recently taken up climbing, which doesn't lead to flare-ups. Without any answers from conventional medicine, she's sought help from acupuncture and osteopathy.

More than anything, the experience means that Jessica is constantly conscious of her brain's physical presence and its vulnerability. "I mean, you're normally not aware of your brain. It's just there—it's like your feet, it's like breathing. But for me, I'm always aware of it."

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