Scientists testing deadly heat limits on humans show thresholds may be much lower than first thought

By weather reporter **Tyne Logan** — ABC Climate Team

Heatwaves

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A world-first study challenges our understanding of how humans cope with extreme heat.

Owen Dillon's heart is pounding. Sweat is dripping down his neck, and he's feeling tired and weak.

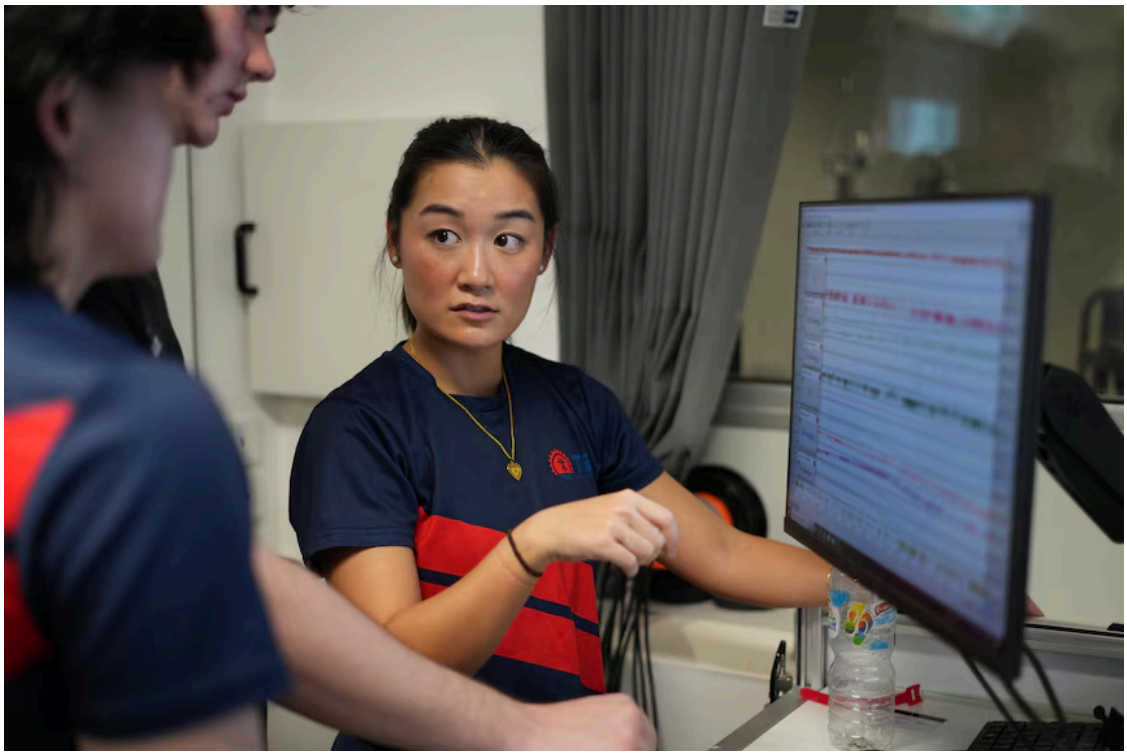
Inside the climate chamber where he's sitting, it's unbearably hot.

It's been set to 54 degrees Celsius, with 26 per cent humidity — a combination believed to be lethal after six hours.

After just a short period of time, he understands why.

Owen has been put into the climate chamber by Jem Cheng, a research fellow at the Heat and Health Research Centre at the University of Sydney.

It's part of a world-first study all about finding out at what point heat becomes deadly.



Dr Jem Cheng wants to find our more about how the human body responds when exposed to lethal levels of heat. *(ABC News: Jack Fisher)*

Fifteen years ago, scientists proposed an environmental threshold at which no person would be able to survive for six hours.

But these conditions have never been tested on humans.

Until now.

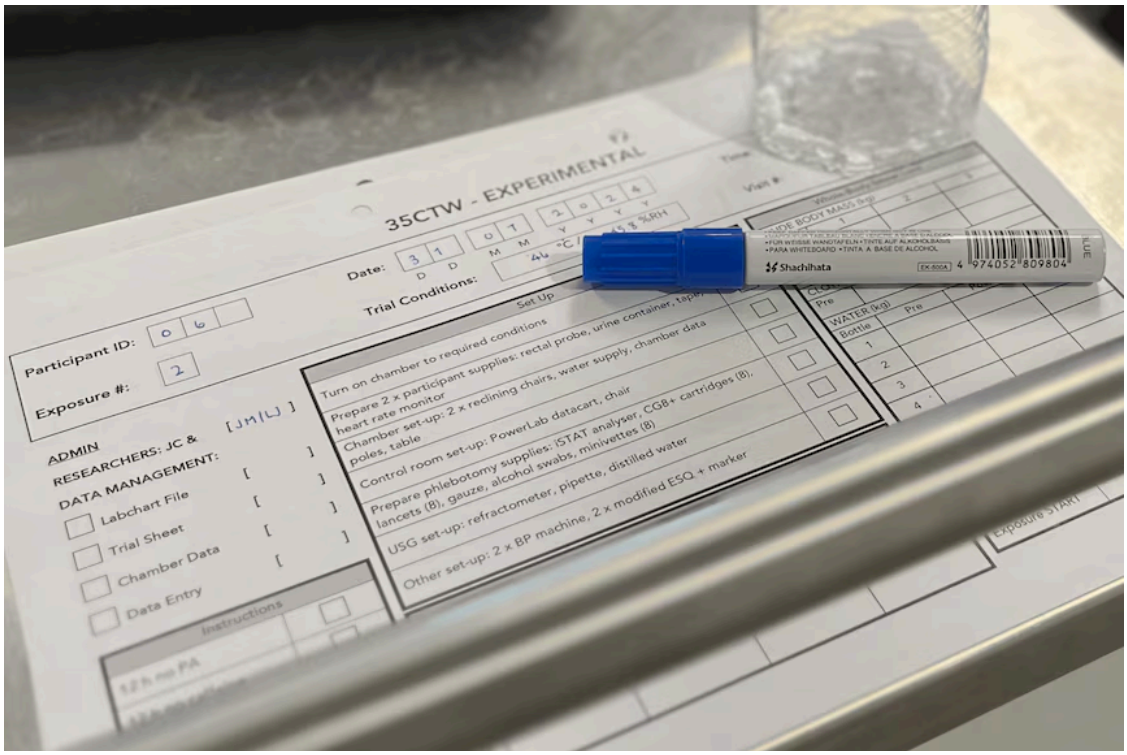
"This study is all about human survivability," Dr Cheng says.

"So we are the first to actually put people in these environments to actually see, physiologically, what is happening to their core temperature or to their heart rate.

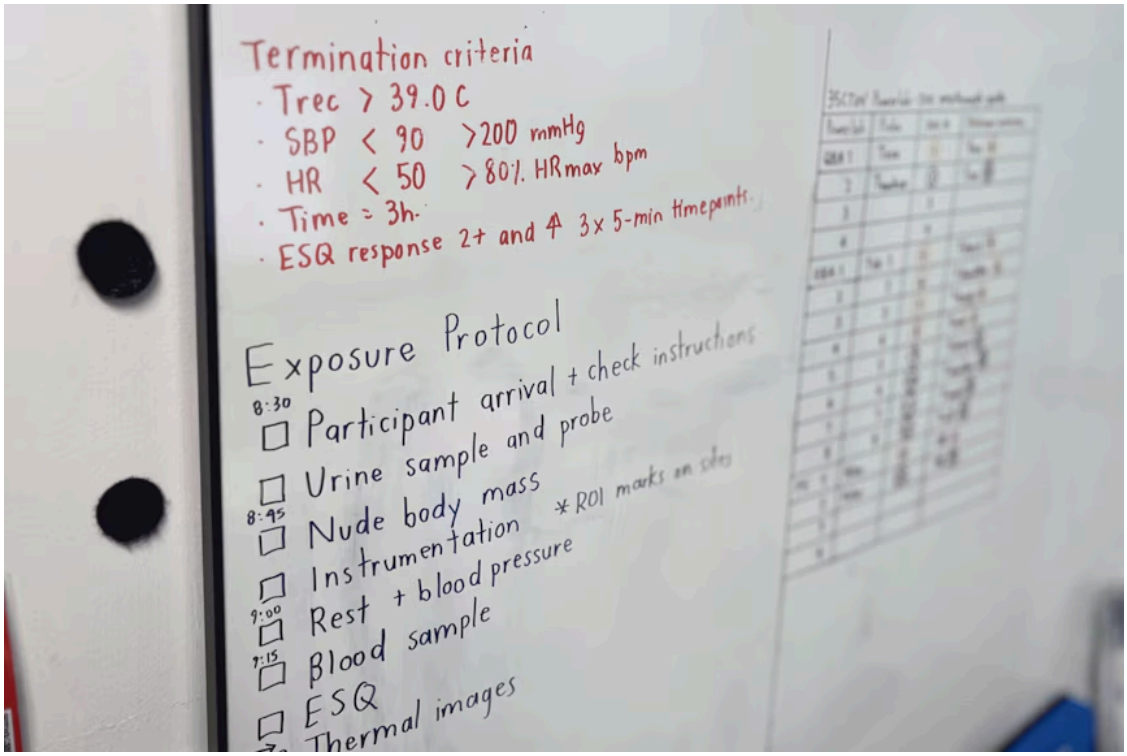
"What is happening to a real human when we put them in these environments?"

Behind this door, Owen Dillon and a female test subject (who chose to stay anonymous) are being exposed to lethal heat. *(ABC News: Kit Mochan)*

On this day, the climate chamber is set to an air temperature of 54C with 26 per cent humidity. *(ABC News: Jack Fisher)*



A team of researchers is closely monitoring how the test subjects respond. *(ABC News: Kit Mochan)*



But of course there is an extensive safety protocol. *(ABC News: Kit Mochan)*

Ody loop experiment starts *(ABC News: Kit Mochan)*

In a warming world, researchers say this question is more important than ever.

Rising CO2 emissions from fossil fuels are driving increases in deadly heat around the world. This summer alone, in the northern hemisphere, thousands have died during extreme heat events.

According to Ollie Jay, a professor of heat and health and the director of the university's Heat and Health Research Centre, there's mounting evidence to show the limit may be lower than first thought.

"We don't want to be sleepwalking into a scenario where we think that these future conditions are going to be survivable when in fact they're not going to be," Professor Jay says.

Owen Dillon is one of the first participants to go through the experiment, having volunteered to be a part of it.

To advance science, Owen Dillon volunteered to be put into lethal heat environments.
(ABC News: Jack Fisher)

"The simple fact is, more and more people are going to be facing, maybe not quite these conditions, but getting close," he says.

"And it's important that we understand what the limits are and what sort of conditions we should expect people to actually be able to work."

As far as his ability to handle heat, researchers say the 31-year-old should be about as good as it gets.

He's young, healthy and fit — currently running 100 kilometres a week as he trains for the Bondi to Manly ultramarathon.

He's allowed to drink as much water as he likes throughout the experiment.

His body is also prepared to handle the heat, having been put through a week of acclimation sessions before the experiment.

"It's essentially in a best-case scenario," Dr Cheng says.

"When your body is fully acclimatised or acclimated to the environment, how do you perform?"

Owen is a marathon runner. *(ABC News: Jack Fisher)*

In the weeks leading up to the experiment, he acclimatised to heat. *(ABC News: Jack Fisher)*

Watch 12s

Owen Dillon's back during the heat experiment *(ABC News: Jack Fisher)*

Researchers are closely monitoring his body's responses. *(ABC News: Jack Fisher)*

The conditions Owen is being exposed to over the course of the study are varied.

Some — like today — are very hot and drier, while others have lower temperatures but much higher humidity.

But, except one, they're all equivalent to a wet-bulb temperature of 35C — the critical threshold at which no human can survive for more than six hours, according to the original theory.

So, what is a wet-bulb temperature, and what does it have to do with how humans cope with heat?

It's a measure that combines the two factors that, together, make heat dangerous to people.

Wet bulb temperature axis *(ABC News: Alex Lim)*

Temperature — how hot the air is — and humidity.

The name comes from the temperature a thermometer would read if its bulb was wrapped in a wet cloth — cooling the thermometer the same way sweat cools a person.

Explaining wet bulb temperature *(ABC News: Alex Lim)*

A wet-bulb temperature of 35C means the air temperature is 35C outside and the humidity is 100 per cent.

Explaining wet bulb temperature *(ABC News: Alex Lim)*

But a thermometer wrapped in a wet cloth will show 35C under many different combinations of temperature and humidity.

Explaining wet bulb temperature *(ABC News: Alex Lim)*

That is because lower humidity means more evaporation, bringing the thermometer temperature down.

That's why on days where the air temperature is hotter than 35C outside, you still might be OK, provided the humidity is low enough.

Explaining wet bulb temperature *(ABC News: Alex Lim)*

This is what Owen is experiencing.

Back in the chair, Owen's body is working overtime to cool down.

But the researchers monitoring his vitals can already see it's not enough to stop his core temperature from rising.

Dr Cheng says there are two factors that can hinder the body's ability to cool down.

Dr Jem Cheng notices Owen's core temperature is rising. *(ABC News: Jack Fisher)*

Watch 6s

Ody Loop temperature on screen *(ABC News: Jack Fisher)*

Thermal image of Owen Dillon's upper body during the heat experiment at the University of Sydney. *(Supplied: University of Sydney)*

Inside the climate chamber, his body's responses are documented. *(ABC News: Jack Fisher)*

One is the environment.

On a very humid day, the air is so full of moisture that the sweat struggles to evaporate.

"You're sweating as much as you can, but the sweat essentially just sits on your body, and that's why you can't cool down," Dr Cheng says.

"That sweat actually needs to be able to evaporate from your body. It's that evaporation that is actually what cools you down."

The other is the limits of the human body itself.

On a very hot, relatively dry day — such as the conditions Owen is currently in — the problem is how much you can sweat in the first place.

"It's sort of the opposite," Dr Cheng says.

"You're producing as much sweat as you can, it's all evaporating, but for you to cool down to the degree that you need to, you need to produce sweat at a rate that is just not possible, even for a heat-acclimated person.

"You max out. Your body physiologically can't produce enough sweat."

Halfway into the three-hour experiment, Owen's core temperature is starting to climb — currently at 38.4C, up from his starting temperature of 37.13C.

From a core temperature of 39C, mild heat exhaustion, such as headaches and faintness, can begin to occur.

At 40C the risk of severe heat exhaustion, including vomiting and disorientation, becomes increasingly likely.

At more than 40.5C, your risk of heat stroke escalates rapidly.

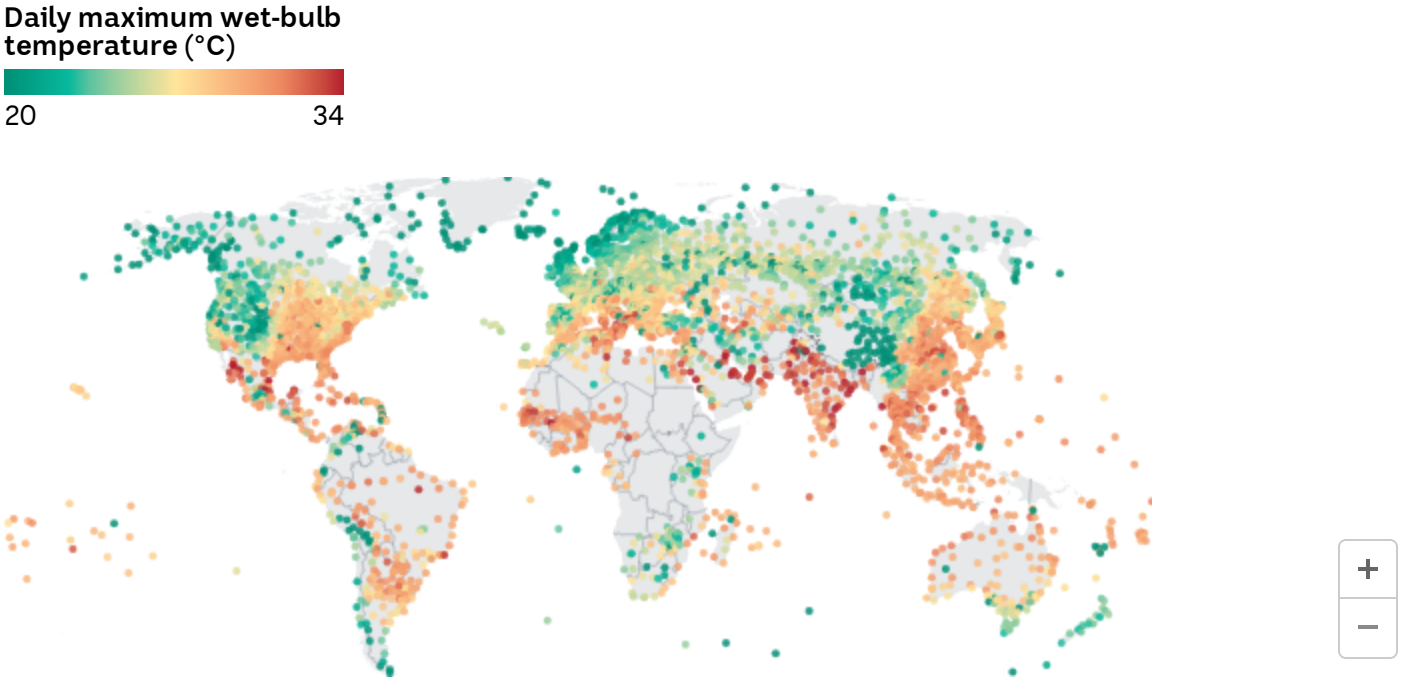
By the time someone's core rises to 43C, a person is all but guaranteed to die.

Wet-bulb temperatures of 35C are rare, even for hot, humid climates, which tend to see higher wet-bulb temperatures.

A 2020 study, published in Science Advances, found there have been a handful of instances, all in the past decade, where places have briefly reached that threshold — in Saudi Arabia and Pakistan.

Dangerous heat across the globe

The number of times wet-bulb readings at or above 30C were observed doubled over the study period.



Analysis of hourly data collected from weather stations within the UK Met Office's HadISN dataset between 1979 and 2017.

ABC / Source: Adapted from Raymond et al., Science Advances, 2020, updated by Colin Raymond 2024 / Get the data

None have reached those thresholds for sustained periods of time, and climate scientists say it's very unlikely they will during this century.

But history shows it doesn't have to be that hot for deaths to occur.

In Australia, since 1900, extreme heat has caused more deaths than all other natural disasters combined.

At least 1300 people died at this year's Hajj pilgrimage to Mecca amid extreme heat. *(AP: Rafiq Maqbool)*

In May a severe heatwave impacted India, with temperatures close to 50C in Delhi.
(Reuters: Anushree Fadnavis)

The Parthenon closed due to a heatwave hitting Athens, Greece, in June. *(Reuters: Louiza Vradi)*

A heatwave also scorched Bangladesh in April with temperatures soaring past 40C.
(Reuters: Mohammad Ponir Hossain)

During 2023, the hottest year on record, more than 47,000 people in Europe are estimated to have died from heat, according to a study published in Nature.

These deaths occurred in conditions that were lower than the 35C wet-bulb threshold.

Professor Jay says that's why it's important to test the conditions on real people. Working with Arizona State University, his team modified the original model to factor in the way the human body works.

The 2023 study, published in Nature Communications, found the thresholds for when heat turns deadly could be much lower in certain climates than first thought.

Explaining wet bulb temperature *(ABC News: Alex Lim)*

Let's bring back that wet-bulb temperature limit. Remember, anything above 35C is not survivable, according to the original study.

Explaining wet bulb temperature *(ABC News: Alex Lim)*

The new study shows that for healthy, young people, it could be as low as 25.8C.

Explaining wet bulb temperature *(ABC News: Alex Lim)*

And for older people, it could be as low as 21.9C.

Explaining wet bulb temperature *(ABC News: Alex Lim)*

The biggest difference is when the air temperature is extremely high and the humidity is low.

"The 35C wet-bulb temperature model is very compelling and in many cases, it's accurate," Professor Jay says.

"What this new model shows is, when you take into account the limitations of human physiology, these upper wet-bulb temperature limits look as though they are much lower under certain types of conditions."

Those "more true" limits are far more likely to occur in a future climate, according to Australian National University professor of climate science Sarah Perkins Kirkpatrick.

A homeless man pours water over himself during an excessive heat warning in Oklahoma City in the US in June 2024. *(REUTERS: Nick Oxford)*

"I would certainly say by the end of the century, we'd be seeing these conditions somewhat regularly during summer seasons," she says.

A man rests during a heatwave affecting the US in New York City in June 2024. *(REUTERS: Jeenah Moon)*

She says places at risk include cities like London, Beijing, Johannesburg, Los Angeles and New York, located in the mid-latitude belt, as well as Australia.

"So when we're thinking about New South Wales, Victoria, South Australia, and especially those desert regions, those thresholds will ultimately be reached," she says.

"But it'll be the temperature and not the humidity that's driving them.

"It ultimately depends by how much the globe warms. The more global warming we see, the higher likelihood of these deadly events occurring and sooner, as well."

Owen reaches his limit

Owen is meant to stay in the chamber for three hours.

But two hours into the experiment, the researchers can see that won't be the case.

His muscles are cramping. His breathing is laboured.

And his core temperature is nearing the experiment's safety cut-off point of 39C.

At two and a half hours, he's pulled out of the chamber.

It's the first time he's not been able to complete the experiment to the full three hours — providing valuable insight to the researchers.

His core temperature rose faster than during the high humidity sessions, despite the wet-bulb temperature being the same.

"Humid conditions have their own sort of more perceptual limitations, that difficulty breathing, because it feels so claustrophobic," Dr Cheng says.

"But in the dry environment, so far, the rate at which [their core temperature] is rising can be one-and-a-half to two times what we're seeing with the more humid conditions."

Planning for a future climate

The researchers recognise there are limitations to their study. After all, the participants are sitting in one spot for several hours, far from the realities of everyday life.

Professor Jay says in some cases, real life could be easier, and in others, it could be harder.

Air conditioning, for instance, goes a big way to providing an escape from hot conditions when they occur.

But outside, in our cities, factors like physical activity, direct exposure to sun, or heavily built-up environments can all make it worse.

Dr Cheng says understanding these risks is particularly important for vulnerable populations in Australia and elsewhere around the world.

Extreme heat will have the biggest impact on vulnerable populations. *(Reuters: Amit Dave)*

Many places lack the resources or infrastructure to combat an increasingly warm climate. *(Reuters: Yahir Ceballos)*

"It's really for a lot of those nations, that don't have a choice but to actually live in these conditions 24/7 … or for people in circumstances where air conditioning is not an option, or areas of the world where manual labour in the field is just sort of their way of life," Dr Cheng says.

"A lot of those parts of the world that are most affected by it, are also the ones that have the least resources, I think, to deal with it."

Professor Jay says allowing temperatures to continue to rise will have global consequences.

"First of all, we might be purely dependent on infrastructure to keep us cool and safe, so we would need a lot of air conditioning," he says.

"The only other way is that people are going to start moving, [either] within-country migration or even, in extreme cases, international migration.

"The downstream impacts of those types of consequences, of mass migration, on resources, employments, all these different types of considerations, could have real profound impacts and serve as a bit of a catalyst for future conflict as well."

The researchers will keep testing the conditions on people until the end of the year.

But in the meantime, it's given both the researchers, and Owen, an important glimpse into where the heat threshold of the human body lies.

"It's harder than I thought it was going to be," Owen says.

"I would say the first time running 80km felt pretty similar to doing 90 minutes in that hot room.

"It's definitely made me a lot more aware of the balance between temperature and humidity, and also a lot more aware of how that's going to impact your ability to perform.

"Now I can look at a weather forecast and say for sure that I will not go running that day."

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