

Innovation Skin phantoms help researchers improve wearable devices without people wearing them

Wearable devices have become a big part of modern health care, helping track a patient's heart rate, stress levels and brain activity. These devices rely on electrodes, sensors that touch the skin to pick up electrical signals from the body.

Creating these electrodes isn't as easy as it might seem. Human skin is complex. Its properties, such as how well it conducts electricity, can change depending on how hydrated it is, how old you are or even the weather. These changes can make it hard to test how well a wearable device works.

Additionally, testing electrodes often involves human volunteers, which can be tricky and unpredictable. Everyone's skin is different, meaning results aren't always consistent. Testing also takes time and money. Plus, there are ethical concerns about asking people to participate in these experiments, including making sure they are informed about the risks and benefits and can voluntarily participate.

Scientists have tried to create artificial skin models to avoid some of these problems, but existing ones haven't been able to fully mimic the way skin behaves when interacting with wearable sensors. To address these limitations, my colleagues and I have developed a tool called a biomimetic skin phantom – a model that mimics the electrical behavior of human skin, making testing wearable sensors easier, cheaper and more reliable.

What is a skin phantom?

Our biomimetic skin phantom is made of two layers that capture the nuances of both the skin's surface and deeper tissues. "Biomimetic" means it imitates something from nature – in this case, human skin. "Phantom" refers to a physical model or device made to mimic the properties of something real, like human tissues, so it can be used for research instead of relying on actual people.

The bottom layer mimics the deeper tissues under the skin. It is made from a gel-like substance called polyvinyl alcohol cryogel, which can be adjusted to have similar softness and electrical conductivity to real biological tissues. We chose this material because these qualities, along with its durability and wide use in biomedical research, make it a good stand-in for the deeper layers of skin.

The

top layer mimics the outermost part of the skin, known as the stratum corneum. It is made from a [silicone-like material](https://doi.org/10.1111/srt.12235) [called PDMS](https://doi.org/10.3390/app10072296), which is mixed with special additives to match the skin's electrical properties. Also widely used in biomedical research, PDMS is flexible and easy to shape to closely replicate the skin's outer layer.

One unique feature of our skin phantom is its ability to mimic different levels of [skin hydration](https://doi.org/10.1016/j.bpj.2013.05.008). Hydration affects how well skin conducts electricity. Dry skin has higher resistance, meaning it opposes the flow of electricity. This makes it harder for wearable devices to pick up signals. Hydrated skin conducts electricity more easily because water improves the movement of charged particles, leading to better [signal quality](https://doi.org/10.3390/s22218510). Improving how dry skin is modeled and tested can lead to better electrode designs.

To replicate the effects of skin hydration, we [introduced adjustable pores](https://doi.org/10.1016/j.sna.2022.113513) into the top PDMS layer of the skin phantom. By precisely changing the size and density of the pores, the model can mimic dry or hydrated skin conditions.

Testing the skin phantom

My team and I tested our skin phantom in several ways to see whether it could truly replace human skin in experiments.

First, we used a method called [impedance spectroscopy](https://doi.org/10.1016/j.snb.2018.08.155) to study the phantom's electrical properties. This technique applies alternating electrical signals at different frequencies and measures the material's resistance to electrical flow, providing a detailed profile of its electrical behavior. Results from the experiments we conducted on five volunteers showed that the phantom's impedance response [closely mirrored](https://doi.org/10.1016/j.sna.2022.113513) that of human skin across both dry and hydrated conditions, with a difference of less than 20% between real skin and the phantom.

We also tested whether wearable devices could pick up signals from the skin phantom and how signal quality changed with different skin conditions. To do this, we recorded [eletrocardiogram signals](https://doi.org/10.1016/j.sna.2022.113513) on phantoms designed to mimic dry and hydrated skin. The results showed clear [differences in signal quality](https://doi.org/10.1016/j.sna.2022.113513): The phantom simulating dry skin had a lower signal-to-noise ratio, while the hydrated skin phantom showed better signal clarity. These findings are consistent with [previous studies](https://doi.org/10.1111/j.1469-8986.2010.01009.x) from other researchers.

Together, our skin phantom closely replicates the way human skin responds to wearable sensors across a range of conditions, including dry and hydrated states. This accuracy makes it an optimal stand-in for real skin in the lab.

Wearable technology

The skin phantom is more than just a testing tool – it's a step forward for wearable health technology. By removing the unpredictability of human testing, scientists can design and improve wearable devices more quickly and effectively. They can also use it to study how skin interacts with medical devices, such as patches that deliver medicine or advanced diagnostic tools.

bottom:6.0pt;margin-left: 0cm;text-align:justify">Our skin phantom is also simple and inexpensive. Each phantom costs less than US\$3 and can be made with standard lab materials and tools. It can be reused multiple times within the same day without significant changes in its electrical properties, though extended use over several days may require adjustments, such as rehydration, to maintain stable performance. This affordability and reusability make the phantom more accessible for labs with limited budgets or resources.</p> <p style="margin-top:6.0pt;margin-right:0cm;margin-bottom:6.0pt;margin-left: 0cm;text-align:justify">As wearable technology becomes more common in health care, tools such as the skin phantom can help make devices more reliable, accessible and personalized for everyone.</p> <p class="MsoNormal" style="margin-top:6.0pt;margin-right:0cm;margin-bottom:6.0pt; margin-left:0cm;text-align:justify"> </p> <p class="MsoNormal" style="margin-top:6.0pt;margin-right:0cm;margin-bottom:6.0pt; margin-left:0cm;text-align:justify">Photo Credit</p> <p class="MsoNormal" style="margin-top:6.0pt;margin-right:0cm;margin-bottom:6.0pt; margin-left:0cm;text-align:justify">Photo by on Unsplash</p> <p class="MsoNormal" style="margin-top:6.0pt;margin-right:0cm;margin-bottom:6.0pt; margin-left:0cm;text-align:justify"> </p> <p class="MsoNormal" style="margin-top:6.0pt;margin-right:0cm;margin-bottom:6.0pt; margin-left:0cm;text-align:justify">Republished from The Conversation</p> <style>@font-face {font-family:Helvetica; panose-1:0 0 0 0 0 0 0 0 0 0; mso-font-charset:0; mso-generic-font-family:auto; mso-font-pitch:variable; mso-font-signature:-536870145 1342208091 0 0 415 0;}@font-face {font-family:"Cambria Math"; panose-1:2 4 5 3 5 4 6 3 2 4; mso-font-charset:0; mso-generic-font-family:roman; mso-font-pitch:variable; mso-font-signature:-536870145 1107305727 0 0 415 0;}@font-face {font-family:Calibri; panose-1:2 15 5 2 2 2 4 3 2 4; mso-font-charset:0; mso-generic-font-family:swiss; mso-font-pitch:variable; mso-font-signature:-536859905 -1073697537 9 0 511 0;}p.MsoNormal, li.MsoNormal, div.MsoNormal {mso-style-unhide:no; mso-style-qformat:yes; mso-style-parent:""; margin:0cm; mso-pagination:widow-orphan; font-size:12.0pt; font-family:"Calibri",sans-serif; mso-ascii-font-family:Calibri; mso-ascii-theme-font:minor-latin; mso-fareast-font-family:Calibri; mso-fareast-theme-font:minor-latin; mso-hansi-font-family:Calibri; mso-hansi-theme-font:minor-latin; mso-bidi-font-family:"Times New Roman"; mso-bidi-theme-font:minor-bidi; mso-font-kerning:1.0pt; mso-ligatures:standardcontextual; mso-fareast-language:EN-US;}h2 {mso-style-priority:9; mso-style-unhide:no; mso-style-qformat:yes; mso-style-link:"Heading 2 Char"; mso-margin-top-alt:auto; margin-right:0cm; mso-margin-bottom-alt:auto; margin-left:0cm; mso-pagination:widow-orphan; mso-outline-level:2; font-size:18.0pt; font-family:"Times New Roman",serif; mso-fareast-font-family:"Times New Roman"; font-weight:bold;}a.link, span.MsoHyperlink {mso-style-priority:99; color:blue; text-decoration:underline; text-underline:single;}a.visited, span.MsoHyperlinkFollowed {mso-style-noshow:yes; mso-style-priority:99; color:#954F72; mso-themecolor:followedhyperlink; text-decoration:underline; text-underline:single;}p {mso-style-noshow:yes; mso-style-priority:99; mso-margin-top-alt:auto; margin-right:0cm; mso-margin-bottom-alt:auto; margin-left:0cm; mso-pagination:widow-orphan; font-size:12.0pt; font-family:"Times New Roman",serif; mso-fareast-font-family:"Times New Roman";}span.Heading2Char {mso-style-name:"Heading 2 Char"; mso-style-priority:9; mso-style-unhide:no; mso-style-locked:yes; mso-style-link:"Heading 2"; mso-ansi-font-size:18.0pt; mso-bidi-font-size:18.0pt; font-family:"Times New Roman",serif; mso-ascii-font-family:"Times New Roman"; mso-fareast-font-family:"Times New Roman"; mso-hansi-font-family:"Times New Roman"; mso-bidi-font-family:"Times New Roman"; mso-font-kerning:0pt; mso-ligatures:none; mso-fareast-language:EN-GB; font-weight:bold;} .MsoChpDefault {mso-style-type:export-only; mso-default-props:yes; font-family:"Calibri",sans-serif; mso-ascii-font-family:Calibri; mso-ascii-theme-font:minor-latin; mso-fareast-font-family:Calibri; mso-fareast-theme-font:minor-latin; mso-hansi-font-family:Calibri; mso-hansi-

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