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# Prototype taps into the sensing capabilities of any smartphone to screen for prediabetes

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Researchers at the University of Washington have developed GlucoScreen, a system that could enable people to self-screen for prediabetes. It uses a modified version of a commercially available test strip (white rectangle on the right) with any smartphone—no separate glucometer required. Leveraging the phone's built-in capacitive touch sensing capabilities, GlucoScreen transmits test data from the strip to the phone via a series of simulated taps on the screen. The app applies machine learning to analyze the data and calculate a blood glucose reading. With early detection, many cases of prediabetes can be reversed through changes to diet and exercise. Credit: Raymond C. Smith/University of Washington

According to the U.S. Centers for Disease Control, one out of every three adults in the United States has prediabetes, a condition marked by elevated blood sugar levels that could lead to the development of type 2 diabetes. The good news is that if it is detected early, prediabetes can be reversed through lifestyle changes such as improved diet and exercise. The bad news? Eight out of 10 Americans with prediabetes don't know that they have it, putting them at increased risk of developing diabetes as well as disease complications that include heart disease, kidney failure and vision loss.

Current screening methods typically involve a visit to a health care facility for laboratory testing and/or the use of a portable glucometer for at-home testing, meaning access and cost may be barriers to more widespread screening. But researchers at the University of Washington may have found the sweet spot when it comes to increasing early detection of prediabetes. The team has developed GlucoScreen, a new system that leverages the capacitive touch sensing capabilities of any smartphone to measure blood glucose levels without the need for a separate reader.

The researchers describe GlucoScreen in a new paper published March 28 in the *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*.

The researchers' results suggest GlucoScreen's accuracy is comparable to that of standard glucometer testing. The team found the system to be accurate at the crucial threshold between a normal blood glucose level, at or below 99 mg/dL, and prediabetes, defined as a blood glucose level between 100 and 125 mg/dL. This approach could make glucose testing less costly and more accessible—particularly for one-time screening of a large population.

"In conventional screening, a person applies a drop of blood to a test strip, where the blood reacts chemically with the enzymes on the strip. A glucometer is used to analyze that reaction and deliver a blood glucose reading," said lead author Anandghan Waghmare, a UW doctoral student in the Paul G. Allen School of Computer Science & Engineering.

"We took the same test strip and added inexpensive circuitry that communicates data generated by that reaction to any smartphone through simulated tapping on the screen. GlucoScreen then processes the data and displays the result right on the phone, alerting the person if they are at risk so they know to follow up with their physician."

Specifically, the GlucoScreen test strip samples the amplitude of the electrochemical reaction that occurs when a blood sample mixes with enzymes five times each second.


Glucoscreen
v1.2
1:31
Your glucose level is
91 mg/dl
Learn more about what this number means
FINISH

Researchers at the University of Washington have developed GlucoScreen, a system that could enable people to self-screen for prediabetes. It uses a modified version of a commercially available test strip (white rectangle at top) with any smartphone—no separate glucometer required. After processing the data transmitted from the test strip, GlucoScreen displays the calculated blood glucose reading on the phone with a link to more information about what the result means. A blood glucose level between 100 and 125 mg/dL would indicate prediabetes. In this example, GlucoScreen returned a reading of 91 mg/dL, which is within the normal range. Credit: Raymond C. Smith/University of Washington

The strip then transmits the amplitude data to the phone through a series of touches at variable speeds using a technique called "pulse-width modulation." The term "pulse width" refers to the distance between peaks in the signal—in this case, the length between taps. Each pulse width represents a value along the curve. The greater the distance between taps for a particular value, the higher the amplitude associated with the electrochemical reaction on the strip.

"You communicate with your phone by tapping the screen with your finger," Waghmare said. "That's basically what the strip is doing, only instead of a single tap to produce a single action, it's doing multiple taps at varying speeds. It's comparable to how Morse code transmits information through tapping patterns."

The advantage of this technique is that it does not require complicated electronic components. This minimizes the cost to manufacture the strip and the power required for it to operate compared to more conventional communication methods, like Bluetooth and WiFi. All data processing and computation occurs on the phone, which simplifies the strip and further reduces the cost.

Researchers at the University of Washington have developed GlucoScreen, a system that could enable people to self-screen for prediabetes. It uses a modified version of a commercially available test strip (white rectangle) with any smartphone—no separate glucometer required. Tiny photodiodes on the GlucoScreen test strip enable it to draw the power it needs to function entirely from the phone's flash—no batteries or USB connection required. Credit: Raymond C. Smith/University of Washington

The test strip also doesn't need batteries. It uses photodiodes instead to draw what little power it needs from the phone's flash.

The flash is automatically engaged by the GlucoScreen app, which walks the user through each step of the testing process. First, a user affixes each end of the test strip to the front and back of the phone as directed. Next, they prick their finger with a lancet, as they would in a conventional test, and apply a drop of blood to the biosensor attached to the test strip. After the data is transmitted from the strip to the phone, the app applies machine learning to analyze the data and calculate a blood glucose reading.

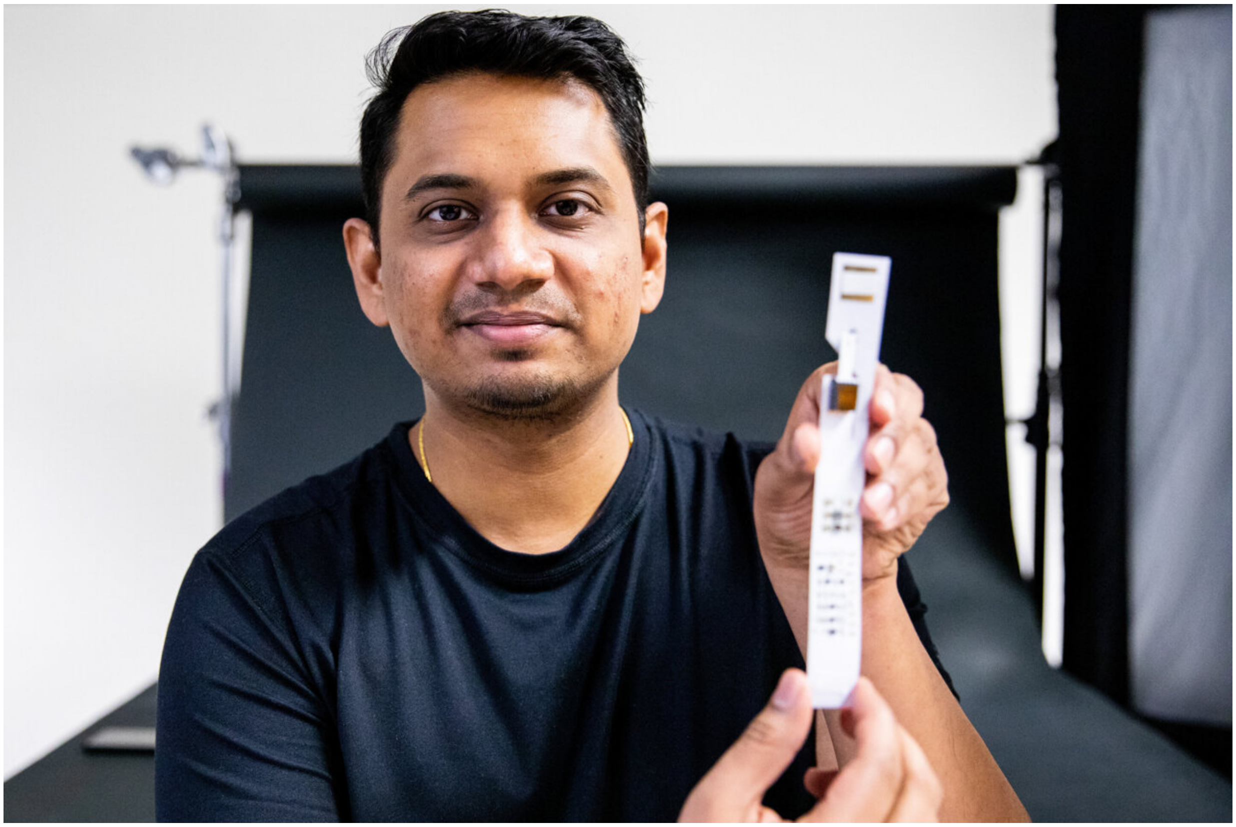
That stage of the process is similar to that performed on a commercial glucometer. What sets GlucoScreen apart, in addition to its novel touch technique, is its universality.

Researchers at the University of Washington have developed GlucoScreen, a system that could enable people to self-screen for prediabetes. It uses a modified version of a commercially available test strip (white rectangular strip) with any smartphone—no separate glucometer required. The GlucoScreen app walks the user through each step of the testing process, which is similar to a conventional glucometer-based test. After affixing the test strip to each side of the phone, a user pricks their finger and applies a drop of blood to the biosensor attached to the strip (shown here). Once the strip transmits the data to the phone via a series of simulated taps on the screen, the app applies machine learning to analyze the data and calculate a blood glucose reading. Note: the blood in this photo is not real. Credit: Raymond C. Smith/University of Washington

"Because we use the built-in capacitive touch screen that's present in every smartphone, our solution can be easily adapted for widespread use. Additionally, our approach does not require low-level access to the capacitive touch data, so you don't have to access the operating system to make GlucoScreen work," said co-author Jason Hoffman, a UW doctoral student in the Allen School.

"We've designed it to be 'plug and play.' You don't need to root [through] the phone—in fact, you don't need to do anything with the phone, other than install the app. Whatever model you have, it will work off the shelf."

The researchers evaluated their approach using a combination of in vitro and clinical testing. Due to the COVID-19 pandemic, they had to delay the latter until 2021 when, on a trip home to India, Waghmare connected with Dr. Shailesh Pitale at Dew Medicare and Trinity Hospital. Upon learning about the UW project, Dr. Pitale agreed to facilitate a clinical study involving 75 consenting patients who were already scheduled to have blood drawn for a laboratory blood glucose test. Using that laboratory test as the ground truth, Waghmare and the team evaluated GlucoScreen's performance against that of a conventional strip and glucometer.



Anandghan Waghmare, a University of Washington doctoral student in the Paul G. Allen School of Computer Science & Engineering, holds up a prototype of the GlucoScreen test strip. Waghmare and his fellow researchers modified a commercially available test strip to incorporate inexpensive circuitry that transmits data generated by the reaction between a person's blood and enzymes on the strip to the phone via simulated tapping on the touch screen. GlucoScreen then applies machine learning to calculate a blood glucose reading on the phone and alert the user if they are at risk of prediabetes. Credit: Raymond C. Smith/University of Washington

Given how common prediabetes and diabetes are globally, this type of technology has the potential to change clinical care, the researchers said.

"One of the barriers I see in my clinical practice is that many patients can't afford to test themselves, as glucometers and their test strips are too expensive. And, it's usually the people who most need their glucose tested who face the biggest barriers," said co-author Dr. Matthew Thompson, UW professor of both family medicine in the UW School of Medicine and global health. "Given how many of my patients use smartphones now, a system like GlucoScreen could really transform our ability to screen and monitor people with prediabetes and even diabetes."

GlucoScreen is presently a research prototype. Additional user-focused and clinical studies, along with alterations to how test strips are manufactured and packaged, would be required before the system could be made widely available, the team said.

But, the researchers added, the project demonstrates how we have only begun to tap into the potential of smartphones as a health screening tool.

"Now that we've shown we can build electrochemical assays that can work with a smartphone instead of a dedicated reader, you can imagine extending this approach to expand screening for other conditions," said senior author Shwetak Patel, the Washington Research Foundation Entrepreneurship Endowed Professor in Computer Science & Engineering and Electrical & Computer Engineering at the UW.

Additional co-authors are Farshid Salemi Parizi, a former UW doctoral student in electrical and computer engineering who is now a senior machine learning engineer at OctoML, and Yuntao Wang, a research professor at Tsinghua University and former visiting professor at the Allen School.

**More information:** Anandghan Waghmare et al, GlucoScreen, *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* (2023). DOI: 10.1145/3580855

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