MEDIA RELEASE

AUTOMATED DIABETIC FOOT SCREENING WITH DIGITAL IMAGING & ARTIFICIAL INTELLIGENCE TO INCREASE SCREENING ACCESSIBILITY AND EFFICIENCY

SINGAPORE, 22 December 2020 (Tuesday) – Singapore is ranked second[1] among developed nations with the highest proportion of diabetics in its population. An average of four[2] diabetic-related foot amputations are performed every day and 1,500[3] of such amputations are carried out annually. 25%[4] of diabetic patients will develop foot ulcers in their lifetime, and 50% of those patients suffer from peripheral arterial disease.

Poor blood circulation and nerve injury arising from diabetes can result in foot complications. If left undetected or poorly managed, severe cases can lead to foot amputations. As such, regular foot screening, which includes the detection of foot deformities, sensory loss, and impaired blood flow, is crucial to managing diabetic conditions. Annual foot screening is recommended and with increased frequency if early problems are detected. Technological innovation could help automate and simplify the process to improve the patient experience and compliance to screening.

To contribute to the war on diabetes in Singapore, Team Live-Betics, comprising a group of students from the Singapore Management University (SMU) School of Information Systems who were taking a course which incorporates the SMU-X experiential learning framework of applying rigorous academic processes to address real-world issues, had embarked on a project with the clinicians from the National University Health System (NUHS) to develop a prototype which would enable diabetic patients to undertake foot screening more regularly and conveniently.

PODIA – a prototype for automated diabetic foot screening

Currently, the frequency of foot screenings varies from once every three months to once a year, depending on the patients' foot risk category. This frequency is low in comparison to the spread of foot infections that could happen in a matter of weeks. In addition, the current foot screening process takes an average of 20-30 minutes depending on whether foot complications are detected, excluding travelling time to polyclinics or limited community screening facilities, and waiting for the screening

[1] LAI, L. (2015). Singapore 'has 2nd-highest proportion of diabetics'. The Straits Times. Retrieved from https://www.straitstimes.com/singapore/health/singapore-has-2nd-highest-proportion-of-diabetics

[2] Agency for Care Effectiveness (ACE). (2019). Retrieved from https://www.ace-hta.gov.sg/public-data/our-guidance/Foot%20assessment%20in%20people%20with%20diabetes%20(June%202019).pdf.

[3] Amputation of limbs regarded as a last resort. Singapore General Hospital. (2018). Retrieved from https://www.sgh.com.sg/news/patient-care/amputation-of-limbs-regarded-as-a-last-resort.https://www.sgh.com.sg/news/patient-care/amputation-of-limbs-regarded-as-a-last-resort

[4] Tresierra-Ayala, M., & García Rojas, A. (2017). Association between peripheral arterial disease and diabetic foot ulcers in patients with diabetes mellitus type 2. Medicina Universitaria, 19(76), 123-126. https://doi.org/10.1016/j.rmu.2017.07.002

to take place. Elderly patients and especially those with mobility difficulties would also need caregiver assistance for these visits.

Guided by SMU Associate Professor of Information Systems Tan Hwee Pink and Dr Chua Horng Ruey, a Senior Consultant with the Division of Nephrology at the National University Hospital (NUH), Team Live-Betics has developed a prototype called PODIA to explore the feasibility of early diagnosis of diabetic foot conditions using Red-Green-Blue (RGB) imaging and thermal imaging technology.

Internet-of-Things (IoT) applications and camera sensors are deployed to take feet images during foot screening. The feet images are then relayed automatically to the secured Amazon Web Services (AWS) cloud servers for analysis. On the backend, computer vision technologies are applied on the RGB images taken of the patient's feet, to detect deformities. For thermal images captured, Artificial Intelligence (AI) algorithms are applied to observe perfusion levels (i.e. blood circulation) in the foot in its resting state - before and after pressure is applied. Ulcers and wounds can also be detected from the thermal images obtained. Authorised healthcare professionals can access the foot screening results through a clinician dashboard.

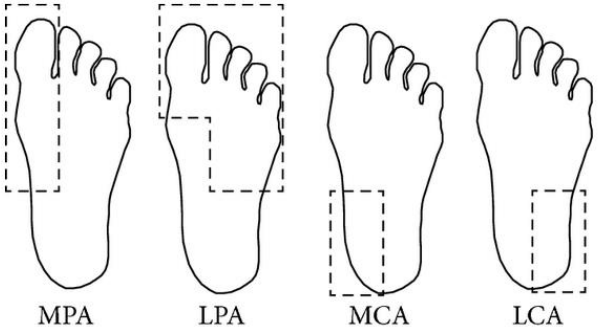
With PODIA, a patient is able to complete self-assisted foot screening by interacting with the Live-Betics web application which has videos with audio input to guide users through the process. AI technology is also used to provide real-time instructions to users. This reduces the healthcare manpower needed to perform the tests required and speeds up the screening process.

PODIA is compact and portable. The minimal space it occupies, makes deployment to community settings and GP clinics feasible. This way, foot screenings can be accessed with greater ease particularly as they are brought nearer to the homes of diabetic patients.

Clinical trial and preliminary findings

A clinical trial was conducted over two weeks with 20 diabetic patients at NUH and another seven healthy volunteers. The preliminary findings are as follow:

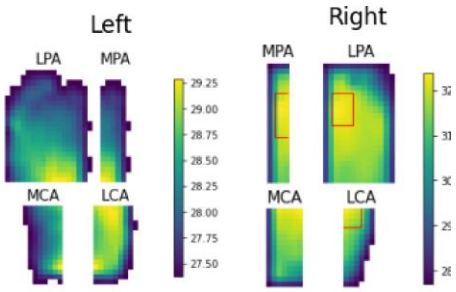
(i) Patients with diabetes mellitus tend to have a much higher mean foot temperature [26.1°C to 31.1°C] across the four sole segments, broadly divided by the main arterial supply, namely the medial plantar artery (MPA), lateral plantar artery (LPA), medial calcaneal artery (MCA), and lateral calcaneal artery (LCA) territories (Taylor & Palmer, 1987), than those without diabetes [22.3°C to 28.3°C]. On average, it is about 2.59°C higher for diabetic patients.



Angiosome concept used for analysis[5]

[5] Taylor, G. I., & Palmer, J. H. (1987). The vascular territories (angiosomes) of the body: experimental study and clinical applications. *Journal of Plastic, Reconstructive & Aesthetic Surgery*, *40*(2), 113-141.

(ii) Ulcers and wounds can be detected in thermal images as hotspots (yellow/green areas demarcated by a red box). These hotspots tend to be at least 1.5°C higher than the mean feet segment temperature.



(iii) Based on the clinical data collected, patients with Charcot foot - a condition in which the weakening of the bones in the foot due to significant nerve damage results in foot deformity - have an average foot temperature of about 26°C to 27°C in normal areas as compared to 29°C to 30°C in the affected areas.

(iv) There is a positive correlation between the presence of diabetic neuropathy (i.e. nerve injury) and higher feet segment temperatures. Those with neuropathy tend to have a much higher mean foot temperature [26.1°C to 31.1°C] across feet segments than those without neuropathy [25.0°C to 29.0°C].

Benefits of PODIA

Based on the preliminary findings, PODIA offers the following benefits to various stakeholders:

a. Patient

- Improves accessibility by allowing more frequent AI foot screenings done in community settings.
- Spends less time on foot screening (10-15 mins) compared to the current process (20-30 mins)
- Facilitates early detection of diabetic foot disease by improved accessibility and uptake of screening, and prompts early medical attention to prevent further foot complications

b. Nurse

- Adds objective information to support the clinical findings from routine foot examination by nurses; the data derived from machine learning algorithms provide a deeper insight of the patient's feet conditions
- Shortens the time taken for foot screening with automation and optimises manpower by reallocating resources to higher-risk patients with complex diabetic foot conditions

c. Healthcare System

- Provides an added layer of high quality foot screening service to cope with the increasing diabetic population in Singapore and the region, especially in places with limited healthcare manpower or expertise in foot screening
- Facilitates remote disease monitoring nearer to home and improves community awareness of the importance of diabetic feet care

SMU Classification: Restricted

Looking ahead

NUHS plans to further enhance the aesthetics and functionalities of PODIA and conduct clinical trials with a larger pool of patients using PODIA. With improved device automation and validated accuracy of its artificial intelligence algorithms, the research team will look into the deployment of PODIA for highly accessible diabetic foot screening in the community.

(Please see Annex A for images of PODIA, and Annex B for quotes by SMU Assoc Prof Tan, Dr Chua and Team Live-Betics)

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About Singapore Management University

A premier university in Asia, the Singapore Management University (SMU) is internationally recognised for its world-class research and distinguished teaching. Established in 2000, SMU's mission is to generate leading-edge research with global impact and to produce broad-based, creative and entrepreneurial leaders for the knowledge-based economy.

Home to over 11,000 undergraduates and postgraduates, SMU comprises six schools: School of Accountancy, Lee Kong Chian School of Business, School of Economics, School of Information Systems, School of Law, and School of Social Sciences. SMU offers a wide range of bachelors', masters' and PhD degree programmes in the disciplinary areas associated with the six schools, as well as in multidisciplinary combinations of these areas.

SMU emphasises rigorous, high-impact, multi- and interdisciplinary research that addresses Asian issues of global relevance. SMU faculty members collaborate with leading international researchers and universities around the world, as well as with partners in the business community and public sector. SMU's city campus is a modern facility located in the heart of downtown Singapore, fostering strategic linkages with business, government and the wider community. www.smu.edu.sg

About the National University Hospital

The National University Hospital is a tertiary hospital and major referral centre with over 50 medical, surgical and dental specialties, offering a comprehensive suite of specialist care for adults, women and children. It is the only public hospital in Singapore to offer a paediatric kidney and liver transplant programme, in addition to kidney, liver and pancreas transplantation for adults.

The hospital was opened on 24 June 1985 as Singapore's first restructured hospital. Each year, the Hospital attends to more than one million patients.

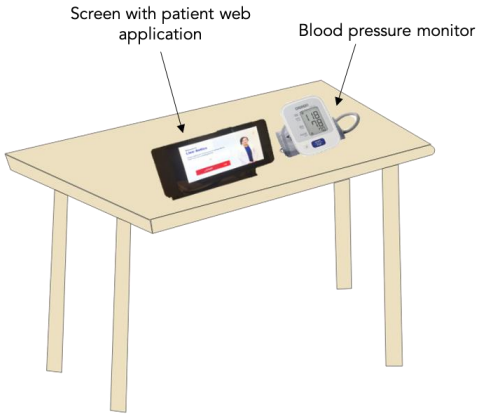
As an academic health institution, patient safety and good clinical outcomes are the focus of the Hospital. It plays a key role in the training of doctors, nurses, allied health and other healthcare professionals. Translational research is pivotal in the Hospital's three-pronged focus, and paves the way for new cures and treatment.

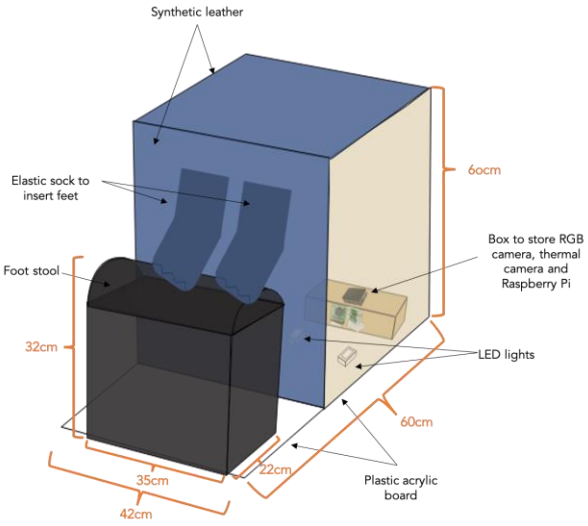
A member of the National University Health System, it is the principal teaching hospital of the NUS Yong Loo Lin School of Medicine and the NUS Faculty of Dentistry.

SMU Classification: Restricted

Annex A

PODIA - Foot Screening Prototype





SMU Classification: Restricted

Annex B

Quotes from SMU Associate Prof Tan Hwee Pink, NUH Dr Chua Horng Ruey and Team Live-Betics

Associate Prof Tan Hwee Pink said, *"Through the experiential learning pedagogy enabled by the SMU-X programme, we were able to bring a real-world healthcare problem as well as clinical domain expertise to our students at SMU, where they can then apply concepts from related modules on the Internet of Things and Smart Healthcare to prototype and test smart solutions with real users."*

Dr Chua Horng Ruey said, "*It takes a village to take care of a patient. With the complexity of chronic diseases today, we cannot provide effective patient care by relying on the health system, alone. The NUHS and SMU-X collaboration is based on a common passion to help our community, and a common vision to improve upstream management for diabetic complications. We merge our medical and technological expertise to create the PODIA initiative. We will continue to improve our device to achieve our goal for 100% patient accessibility and compliance to diabetic foot screening.*"

Ms Vinnie Chu Yi Xuan, a member of Team Live-Betics said, "*During our user testing at NUHS we had the chance to interact with diabetic patients with varied foot conditions. Many were senior, came unaccompanied for their podiatrist appointment, and faced mobility issues. We witnessed their struggle to complete simple tasks. This served as a reminder of the benefit of making foot screening more accessible and readily available to maintain good foot health amongst diabetics."*