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Engineering a Diabetic Foot Lesion Predictor to Stop Walking in Time

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BACKGROUND

Diabetic foot is the most frequent condition among the complex complications of diabetes, occurring in 25% of patients [1]. There are two options for patient monitoring and assessment: objective clinical outcome measures (OCOMs) and patient-reported outcome measures (PROMs) [2]. PROMs provide a method of obtaining functional status and wellbeing [3] and may be important in complementing clinical measures. The current standard of care for diabetic foot prevention is education, regular evaluation, therapeutic shoes, and customized insoles. Currently, there are several clinical methods (OCOMs) used to assess diabetic foot. It would be, as a preventive measure, of great importance to identify precursor signs of skin lesions that would constitute the basis for preventive actions. Yet, as the literature shows there are no alert systems nor medical devices for the prevention or early detection of diabetic foot [4][5].

OBJECTIVE

Proof of concept of first pressure measurements to predict diabetic foot lesions.

METHODS

Literature review (PRISMA) of physical magnitudes and their links with early signs of plantar and non plantar diabetic foot surface damage [6]. Use of an experimental setup to obtain pressure values at specific anatomical locations.

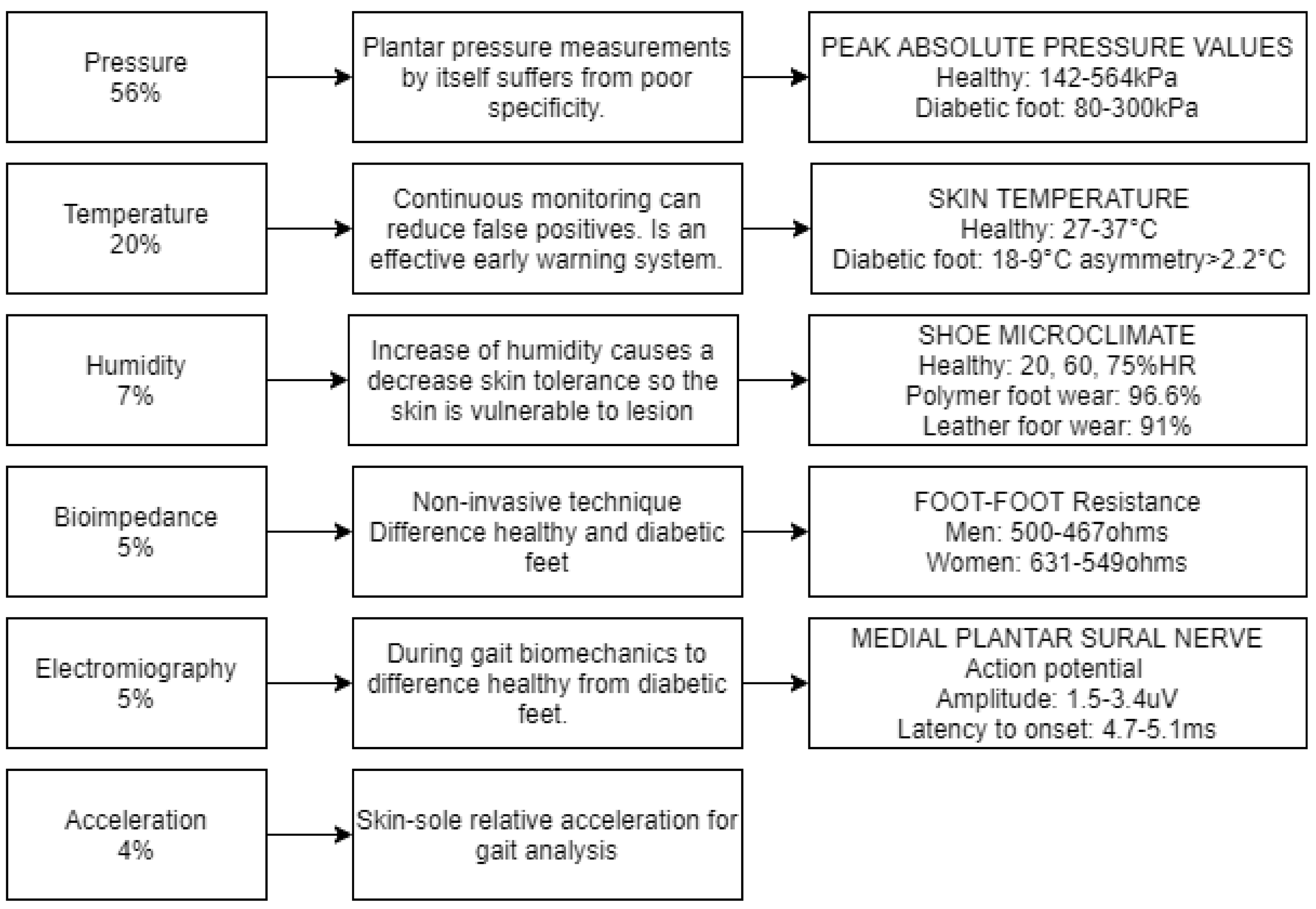

Figure 1. Effect of lesion related variables on diabetic foot outcome and normal values.

RESULTS

The search in databases returned a total of 4366 papers. After removal of duplicates and screening of titles and abstracts, 81 publications were included for qualitative synthesis by its physical principle. The most important physical magnitude is pressure, shown in figure 1. It represents 56% of 110 measurements identified among 81 articles.

Physical magnitudes of the normal and ulcered foot have significant disparities. Skin temperature increases with inflammation and decreases in absence of neuropathic or vascular activity and depends upon ambient temperature. As humidity defines microclimates, experiments have recorded 96.6% and 91% relative humidity (RH) in polymer and leather footwear, respectively. Bioimpedance, foot-to-foot resistance, electromyography and acceleration are being used to characterize gait which is affected by diabetic foot etiology.

We built foot templates with 10 key areas (24 FSR sensors) that allow to see the plantar pressure footprint, figure 2. The static model captures a picture that contains ten pressure thresholds of the footprint (eg. 664 KPa for internal heel area of a woman of 23 years old), figure 3. The dynamic model shows 80 footprint pictures in a period of 5 seconds (16 frames per second) figure 4.

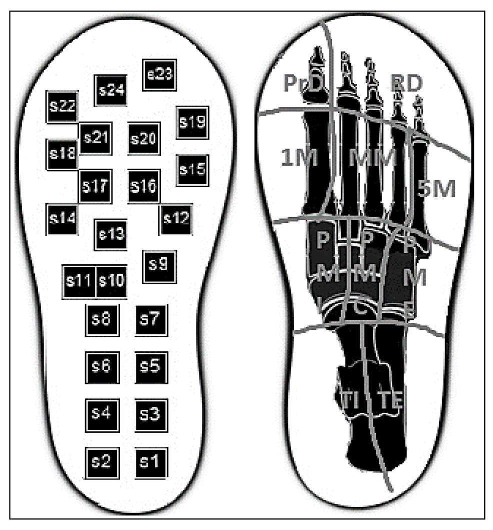

Figure 2. Anatomical location of 24 sensors grouped in 10 areas.

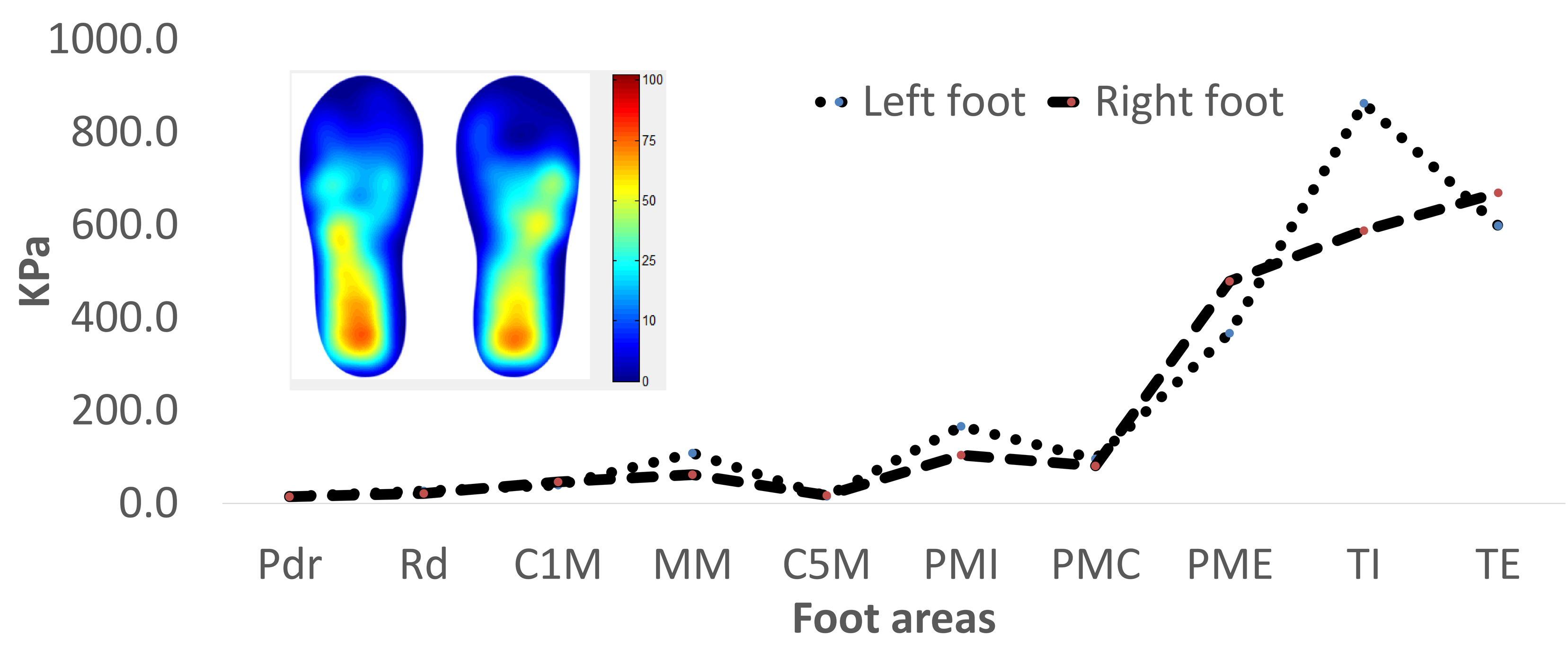

Figure 3. Pressure as meassured in ten foot sole areas during static stand. Inset shows the same measurements after Gaussian low pass filter.

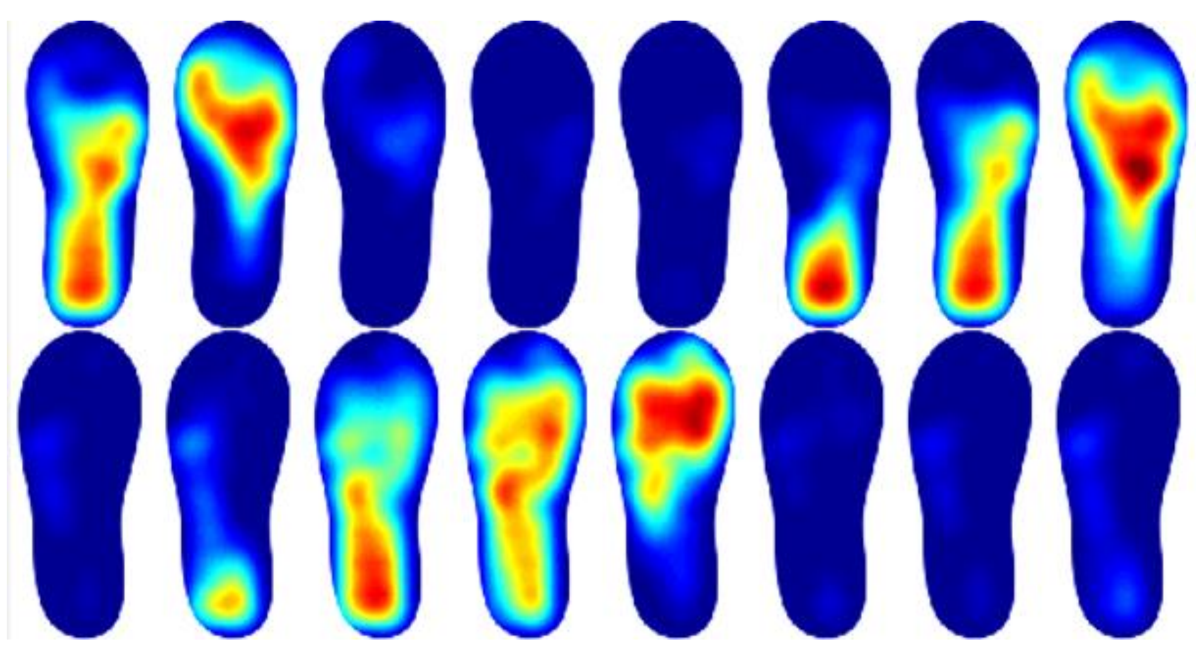

Figure 4. Pressure representation during one gait cycle.

DISCUSSION

Six physical magnitudes were selected for their possible link with early signs of plantar and non plantar foot surface alteration. The normal pressures of our 24 FSR insole sensors were in the normal values range [7]. Therefore, the possibility to reduce the amount of sensors to five key sole points is there to be studied. Besides, to improve the ergonomic design, the use of FSR as noncontact bioimpedance electrodes will also be studied.

It was noticed that the use of accelerometers for gait analysis is increasing due to their portability so it can be combined to establish a possible threshold to distinguish normal from almost ulcered foot.

CONCLUSION

The proof of concept to estimate podal energy during gait strated with this literature review. Six parameters are good candidates for the prediction of foot pre lesions during gait. Emphasis is placed on the combination of physical magnitudes to estimate dissipated energy during gait to eventually trigger alerts for the diabetic patient. Moreover it is necessary to improve the self-care questionnaire to monitor the diabetic patient foot during gait in real life.

[1] G. Rescio, A. Leone, L. Francioso, and P. Siciliano, "Smart insole for diabetic foot monitoring", vol. 539. Springer International Publishing, 2019.
[2] Fernández-Torres R., Ruiz-Muñoz M., Pérez-Panero A., "Instruments of choice for assessment and monitoring diabetic foot: a systematic review", Journal of Clinical Medicine, 2020.
[3] Ortega-Avila A., Cervera-Garvi P, Ramos-Petersen L., Chicharo-Luna E., Gijon-Nogueron G., "Patient-Reported Outcome Measures for Patients with Diabetes Mellitus Associated with Foot and Ankle Pathologies: A Systematic Review", Journal of Clinical Medicine, 2019.
[4] Bus P. R. , Armstrong S. A., Van Deursen D. G., Lewis, R. W., Caravaggi, C. F., "IWGDF guidance on footwear and offloading interventions to prevent and heal foot ulcers in patients with diabetes," Diabetes. Metab. Res. Rev., vol. 32, no. 32, pp. 25–36, 2016.
[5] Rescio G., Leone A., Francioso L., and Siciliano P., "Sensorized Insole for Diabetic Foot Monitoring," Proceedings, vol. 2, no. 13, p. 860, 2018.
[6] Morales I., Simini F., "Physical Magnitudes Measurements for the Design of Diabetic Foot Lesion Detectors: A Review", Congress SABI2020, Uruguay.
[7] Gurney J., Kersting U., Rosenbaum D., "Between-day reliability of repeated plantar pressure distribution measurements in a normal population", Gait & Posture 27, Science Direct, 2008.