Relationship between temperature and plantar stress in treadmill and ground walking in a healthy participant

A. Haron[1], L. Li[1], J. Shuang[1], M. Mansoubi[2], G. Massey[2], D. Crosby[1], C. Lin[1], H. Dawes[2], G. Cooper[1], A. Weightman[1]
[1]Medical Engineering Research Group, School of Engineering, University of Manchester, United Kingdom
[2]NIHR Biomedical Research Centre, University of Exeter, Exeter, United Kingdom
Email: andrew.weightman@manchester.ac.uk

Summary

This study used novel sensing insoles to measure plantar temperature, normal, and shear stress (TNS) data during treadmill and ground walking in a healthy participant. Results showed plantar temperature increased during gait and decreased during rest. Ground walking had lower temperature gradients than treadmill walking at the hallux and calcaneus, despite similar peak stresses, whilst the first metatarsal head temperature gradients remained similar for different walks. This may be evidence of differences in thermal regulation in different anatomical sites during activities more representative of daily living. The study demonstrated the potential of smart insoles to measure plantar tissue biomechanics properties which could be used on people living with diabetes to prevent foot ulceration.

Introduction

By 2030, more than 50 million people in the UK are estimated to have diabetes, and up to 25% will develop a diabetic foot ulcer (DFU) in their lifetime [1]. Smart insoles offer a low-cost and minimally invasive prevention method enabling self-management but also present an opportunity to collect novel data to improve clinical understanding of DFU. Recent work from our group has developed novel in-shoe shear sensors [2] and TNS insoles which has shown a statistical correlation between plantar stress and temperature [3]. Previous studies focused on a single laboratory-based walk and rest period which is not fully representative of activities of daily living. This study aimed to measure TNS data for periods more representative of activities of daily living.

Methods

A patient specific smart TNS sensing insole (Figure 1), similar to that used in our previous study [3] was used to measure dynamic TNS data at the calcaneus, first metatarsal head and hallux in a healthy participant (44 years old, 185 cm height, male, 80 kg). They sat, stood still then walked on a treadmill twice with a rest in between, finishing with a ground walk. Data was analyzed via MATLAB (MathWorks, Boston, US) to obtain average (mean) peak stresses, cumulative sum of stresses squared (a measure that reflects strain energy, akin to pressure time integral, [3]), change in temperature and temperature gradient.

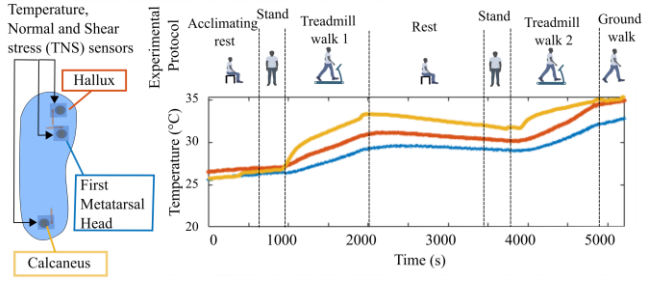

Figure 1: (Left) TNS sensors locations at the insole. (Right) Protocol and temperature results, showing temperature increased during gait activities and recovered during rest.

Results and Discussion

Temperature increased during all gait activities and decreased during the rest period, like our previous study [3]. Ground walking had lower temperature gradients than treadmill walking at the hallux and calcaneus, despite similar peak normal and shear stresses (less than 32% difference). Negligible differences in temperature gradients were seen in the first metatarsal head (Table 1). These temperature gradient differences may stem from factors affecting heat dissipation, such as thermal tissue properties.

Conclusion

This study measured novel TNS data in the laboratory representative of activities of daily living and shown that there are differences in rates of change of temperature during the activities, despite similar peak stresses. Differences were also observed in different anatomical locations. Further work is needed to analyze data for more participants and clinical groups.

Acknowledgments

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References

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Table 1: [A] Temperature gradients (°C/min), [B] mean peak normal, [C] anterior-posterior shear stresses (kPa) for treadmill walks (1,2), rest and ground walk (walk 3) showing different rates of temperature gradients between anatomical locations, but similar peak stresses.

Locations	Walk 1			Rest	Walk 2			Walk 3		
	A	B	C	A	A	B	C	A	B	C
Hallux	0.22	224	74	-0.02	0.26	242	66	0.08	237	69
First metatarsal head	0.15	282	106	0.01	0.19	257	100	0.17	268	98
Calcaneus	0.38	254	100	-0.05	0.20	253	80	0.04	252	101