# EFFECTS OF VARYING THE ENVIRONMENTAL CONDITIONS ON IN-SHOE TEMPERATURE

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## INTRODUCTION

There are inherent difficulties with measuring foot-skin temperature when a shoe is worn, as the presence of sensors and connecting leads can cause undesirable reactions from the skin and disturb the natural foot-shoe environment. Typically, when skin temperatures are measured directly (especially in extreme conditions) there are large variations between the foot skin temperatures of different subjects. By measuring the in-shoe temperatures, it is thought that the variation between subjects can be reduced so as to create a narrow envelope of in-shoe temperatures within which most subjects will statistically lie.

## METHODS

Before each test, subjects were required to wash their feet in a controlled bath at 32°C. Nine subjects were tested in an enclosed environmental chamber for 80minutes that comprised of 35minutes of acclimatizing rest, 10minutes of light stepping exercise and 35minutes of seated recovery. The chamber's controlled ambient conditions were varied through a series of temperature and relative humidity (RH) combinations. Each subject participated in 5 experiments, with all subjects wearing the same design of shoe. These conditions varied from cool (15° C) to mild (25°C) to hot (35°C), with RH being maintained at 50% and 70%. In-shoe temperature was measured in 6 locations around the shoe, including the midfoot, the lateral metatarsal area, the arch, the heel, and 2 in the toe region. Wind speeds in the chamber were recorded to be 0.5 ± 0.10 m/s, and the subjects' perception of comfort was recorded every 5 minutes according to the scales used by Covill (2002). An aural thermometer recorded subjects' approximate body temperature every 5 minutes, and their heart rate was logged throughout each test.

## RESULTS AND DISCUSSION

Table 1 is a summary that shows the average temperatures for the 3 activity periods in each environmental condition. A two-way analysis of variance (ANOVA) was carried out to investigate if there were significant differences in the temperatures recorded at each shoe zone, and between each environmental condition. For each condition there was significant evidence ($P < 0.05$) to suggest the in-shoe temperature differs at various locations around the foot. There was also a significant difference ($P < 0.05$) between the in-shoe temperatures measured at different ambient temperatures. There was no significant difference, however ($P >> 0.05$), between the in-shoe temperatures measured in different environmental relative humidity levels at the same temperature.

For the cooler conditions (15°C and 25°C), the arch was the warmest in-shoe region (Figure 1), while in hotter conditions the midfoot took over as the warmest region. The toe region was consistently the coolest in-shoe zone, with the lateral side being colder than the medial.

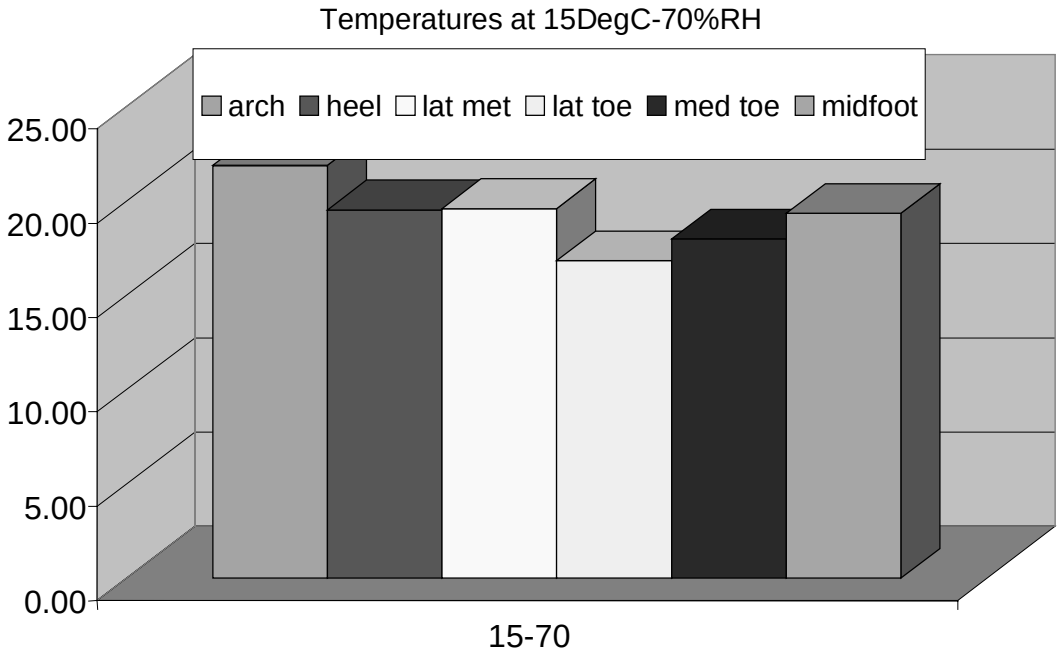
**Table 1:** Average In-Shoe Temperature over all shoe-zones for each condition (temperature - RH%) over each activity period.

| | **15°C – 50%** | **15°C – 70%** | **25°C – 50%** | **35°C – 50%** | **35°C - 70%** |
|---|---|---|---|---|---|
| **Rest Period** | 18.97 ± 1.12 | 19.19 ± 0.90 | 26.19 ± 1.14 | 34.87 ± 1.91 | 35.33 ± 0.97 |
| **Exercise Period** | 19.67 ± 1.25 | 19.03 ± 1.19 | 27.37 ± 1.31 | 35.71 ± 1.44 | 36.03 ± 0.89 |

| | | | | | |
|---|---|---|---|---|---|
| **Recovery Period** | 18.81 ± 1.35 | 18.76 ± 1.01 | 27.44 ± 0.85 | 36.03 ± 1.24 | 36.15 ± 1.01 |

There was a difference between the average foot temperature for each subject, however the magnitude of the difference was much less when compared to conventional skin temperature measurements (Kuklane, 1998).

**Figure 1:** The average In-shoe temperatures for each shoe-zone in the condition 15°C 70%RH




**SUMMARY**

There were significant differences in the temperatures measured around the inside of the shoe as they varied with the ambient conditions. These temperatures however, did not vary between subjects as greatly as in typical skin temperature measurements. Hence, the in-shoe temperature measurement is a valid method for reducing subject variability in the measurement of in-shoe climate.

**REFERENCES**

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**ACKNOWLEDGEMENTS**

The authors would like to thank the Chelsea School for the use of the environmental chamber.