Effect of thermodynamic insole on plantar skin temperature during exercise run in cold environment

Pierre Schiano-Locurcio and Grégory Doucende

Laboratoire Interdisciplinaire Performance Santé Environnement de Montagne, UR4604, Université de Perpignan Via Domitia, Font Romeu, France

1. Introduction

Ultra-trail-running (UTR) is characterized by sequences of uphill and downhill performed in a natural environment during a long period at low velocities. UTR could be realized in temperate, hot or cold environment. Physiological adaptation to cold environment is characterized by a redistribution of circulatory balance leading to a peripherical vasoconstriction to preserve central temperature (McMahon and Howe 2012). Consequently, skin temperature in extremities, as hand or foot, is dramatical reduce from 33–34 °C to 28–27 °C (Yamazaki 2015). So, input of heat during UTR on foot could allows runners to run across a longer period in cold environment.

Heat input to the feet can be achieved from heated insoles. Classically, these devices require the use of battery making them very heavy and therefore not suitable for use in UTR. ExtremWear® insoles are based on a thermodynamic principle (Carnot cycle) (Feidt 2020) which uses foot pressure when running instead of an electric compressor. The insole is therefore composed of closed cells (neither letting in nor out of air) in two parts made of two different materials separated by a nozzle. When placing the foot, the alveoli is rounded and very flexible will deform and thus expel the air and compress it in the second part of the alveoli on the other side of the insole. This second part being much more rigid (presence of reinforcements) this prevents the deformation of the latter allowing the overpressure of the air. The increase in air pressure will cause the air temperature to increase in the alveolus. So, if we place the rigid alveoli towards the foot, we will then have a heating of the air in the alveoli located against the feet and vice versa (Figure 1).

The purpose of this study was to determine if the utilization of thermodynamic insole could increase foot temperature during an exercise run in cold environment. We hypothesize that thermodynamic principle include in these insoles could increase foot temperature during an exercise run in cold environment.

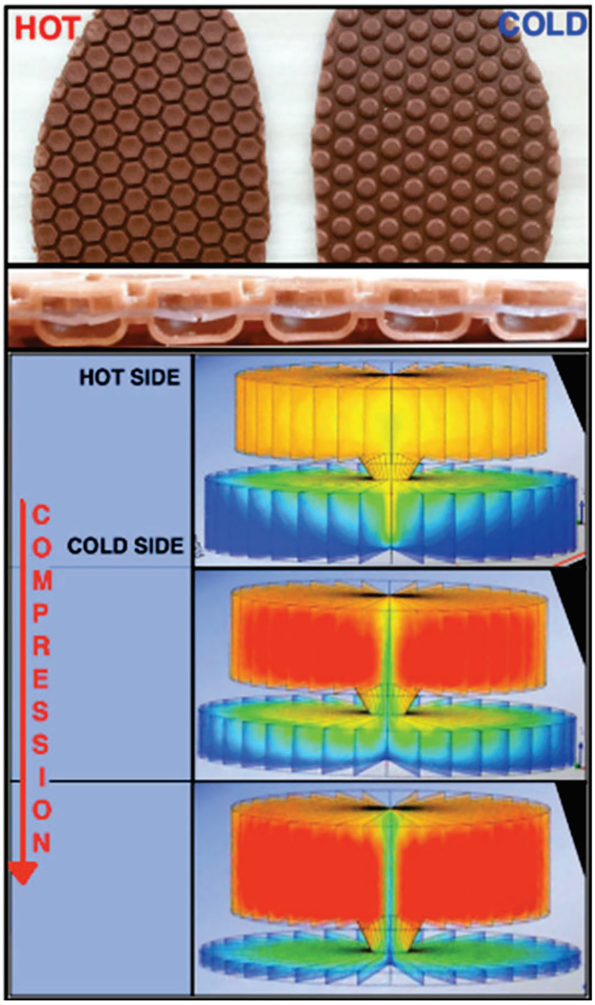

Figure 1. Explanation of ExtremWear® insole technology.

2. Method

2.1. Participants and study design

Twelve runners participated to this study (age: 23 ± 2 years, height: 168 ± 19 cm, weight: 82 ± 15 kg). Study took place in natural environment on an athletic track of 400 meters. Runners were randomly fitted (right or left foot) with a thermodynamic insole (ExtremWear®, Solecooler, France) and a placebo sole (Figure 1). They had to perform a 45min exercise run between 70 and 75% of their theoretical maximal Heart Rate (HR) calculated from the formula 210 – (0.69 * Age). There was no warm-up before exercise to observe the rise in plantar temperature over the first few minutes.

2.2. Data collection

Each participant was equipped with two Datalogger thermometers at each foot (Elitech, RC-4, England) placed, in contact with the skin, on the sole and the kick of feet. Temperature of sole and kick of feet every 10 minutes

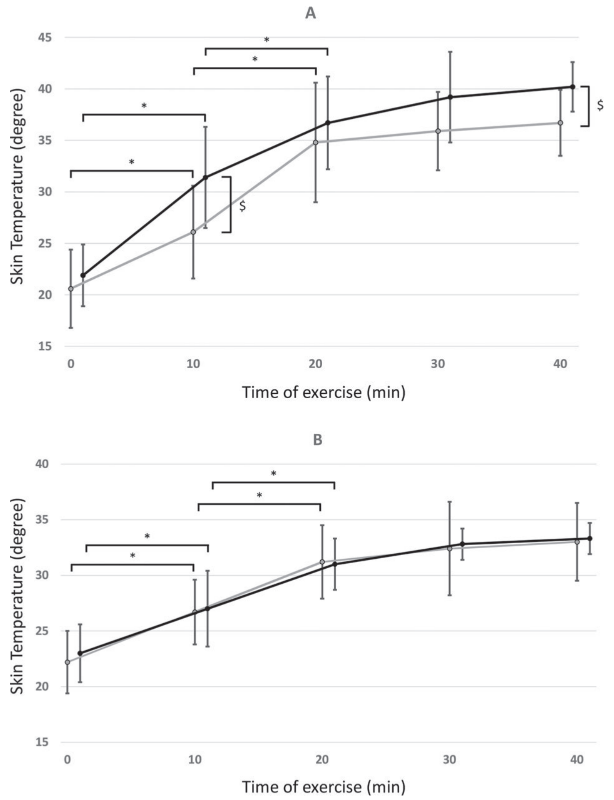

Figure 2. Evolutions of skin temperature in the sole (A) and kick (B) of the foot during a 45-minute run in cold environment without (grey) and with (back) thermodynamic insole. *Significant difference between previous step and $ significant difference between both conditions (without or with insole).

were determined at posteriori with a specific software (Elitech LogWin, England). HR of subjects were monitored during exercise run with cardio-frequencemeters (Ambit 3 Peak, Suunto, Finland). Environmental temperature were continuously mesured during exercise (Kestrel 5400 LinK, Kestrel Meters, USA).

2.3. Statistical analysis

Data are presented under the form mean ± standard deviation. Statistical analysis has been realized with the software Statview (version 5.0). A student T-test has been used to compared temperature data measured at rest and during exercise. Significant differences across kinetics of temperature were performed with a repeated-measures ANOVA and post hoc Bonferroni correction. Size effect was performed from F values for ANOVA and the D-test of Cohen for student T-test. Statistical significance for all analyses was assumed at $P < 0.05$.

3. Results and discussion

Evaluations were carried out in a cold environment of −0.9 ± 3.1 °C. These temperatures are conventionally found in UTR's run in a cold environment. During exercise, subjects ran at 71.6 ± 3.7% of maximal HR which classically corresponds to the intensity of exertion found in UTR (Scheer et al. 2020).

Resting skins temperatures (kick and sole) were similar in both conditions (without or with thermodynamics insoles) (Figure 2) and reflected skin temperature of cold environment (Yamazaki 2015). During exercise, skins temperatures (kick and sole) increased for 20 minutes and then stabilize. No differences were found during exercise in both conditions (without or with thermodynamics insoles) in kick skins temperatures (30.8 ± 3.1 °C *versus* 31.0 ± 2.0 °C, *NS*). However, our results underline a greater skins temperature during exercise on sole skins when subjects wore thermodynamics insoles (33.4 ± 4.0 *versus* 37.1 ± 3.8 °C, $p < 0.05$, $D = 0.85$). Interestingly, temperatures recorded after 10 minutes of exercise suggested that wearing thermodynamic insole increases skin temperature more quickly at the start of exercise in the soles of the feet (26.1 ± 4.5 °C *versus* 31.4 ± 4.9 °C, $p < 0.05$, $F = 0.72$) allowing to fight the cold sensation from the beginning of the exercise. Moreover, our results showed that thermodynamic insoles wear allows to obtain a higher skin temperature at the end of the exercise (36.7 ± 3.2 °C *versus* 40.2 ± 2.4 °C, $p < 0.05$, $F = 0.69$) suggesting that organism will easier fight against cutaneous vasoconstriction in the feet and thus allow runners to run in better conditions in a cold environment during UTR races.

4. Conclusion

Our results pointed up that the utilization of thermodynamic insoles without battery significantly increase plantar skin temperature during an exercise run in a cold environment. The principle and characteristics of these insoles (lightness) allow us to consider their use during UTR races taking place in a cold environment. Finally, the elasticity of the sole could allow to consider a potential gain of the energy cost, so additional studies will be necessary in order to consider this opportunity.

Conflict of interest

We declare no conflict of interest with Solecooler company.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Feidt M. 2020. Carnot cycle and heat engine: fundamentals and applications. Entropy. 22(3):348.

McMahon, J. A., Howe, A. 2012. Cold weather issues in sideline and event management. Curr Sport Med Report. 11(3):135–141.

Scheer, V. Basset, P. Giovanelli, N. Vernillo, G. Millet, GP. and Costa, RJS. 2020. Defining off-road running: a position statement from the ultra sports science foundation. Int J Sport Med. 41(5):275–284.

Yamazaki, F. 2015. The cutaneous vasoconstrictor response in lower extremities during whole-body and local skin cooling in young women with a cold constitution. J Physiol Sci. 65(5):397–405.

KEYWORDS Trail-running; extreme conditions; temperature

gregory.doucende@univ-perp.fr