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Original Research Article

Lateral Dorsal Foot Temperature during Thirty Minutes of Treadmill Running in Running Shoes with Mesh versus Vinyl Uppers

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Abstract

Introduction: There are few studies exploring the effects of shoe or sock material on foot temperature during running, and most are single-sex. **Purpose:** This study investigated how shoe material (mesh versus vinyl upper) affected lateral dorsal foot temperature (LDFT) during thirty minutes of treadmill running in both females and males. **Methods:** Twenty subjects completed two 30-minute running trials, one each in mesh and vinyl running shoes. Thermometers were attached to the dorsal lateral aspect of the right foot against the skin and against the sock. Visual analogue scales assessed subjects' perceptions of foot comfort and foot temperature. **Results:** There were no statistically significant differences in physiological temperature between shoes at any time point, though subjects perceived their feet as being warmer and less comfortable when wearing the vinyl shoe. Perceived foot temperature correlated significantly and positively with actual LDFT, and significantly and negatively with perceived comfort. **Conclusions:** These findings suggest that the LDFT will be similar regardless of shoe upper material, but that shoe upper material will impact on a runner's perceived foot comfort and perceived foot temperature. The lateral dorsal aspect of the foot may not be the most representative site of overall foot temperature.

Key Words: Comfort, Perception, Sweat, Thermometer

Introduction

Footwear selection is critical for runners[1,2]. Runners are faced with countless options, which differ in functionality, structure, and material. Three criteria are advised for shoe selection: performance, injury protection, and comfort[3]. These criteria are affected by and in turn affect each other.

Foot heat dynamics are important to understand not only from the standpoint of homeostasis, but also because they can affect athlete perception of foot comfort[4–8], both of which in turn can impact on athlete performance or running economy[8,9]. In the context of running, foot heat accumulation can arise from two sources: internally from metabolism; or externally from heat transfer at the surface, including friction and other contact forces, or ambient air temperature[10]. Heat dissipation can occur locally at the foot through evaporation or convection, or through transfer to other body regions that sweat more, such as the trunk[5,11]. Increases in foot temperature are associated with concomitant increases in foot sweating rates, primarily at the dorsal surface[12].

Shoes and socks alter the heat dynamics microenvironment around the foot, and most previous investigations have focused on either socks or shoes in isolation. Sock studies differed remarkably in experimental design characteristics (Appendix 1). Some reported no differences in actual foot temperature based on different socks[4,5,7], though some reported pronounced[13,14] or inconsistent[6] differences. Of the sock studies that asked subjects to subjectively rate foot temperature, four reported differences between socks[4,5,7,15], two reported no differences[6,16], and one was inconclusive as different statistical models yielded different conclusions[17]. As shown in Appendix 1, widely discrepant experimental design differences may explain differences between studies, and most did not directly control for shoes. It is interesting to note the rationale for sock selection in these studies was most frequently based on fiber composition, yet a recent review has concluded that fabric structure may be a more important variable[18].

Fewer studies have assessed shoe effects. One pilot study of sixteen young adult males who ran for five minutes on a treadmill in two different mesh shoes and two different vinyl shoes (wearing the same sock model across trials and subjects) found no differences in actual or perceived foot temperature across the four shoe models[4]. This study used temperature probes in two locations, one between the skin and sock and another between the sock and shoe, both on the dorsal lateral aspect of the foot. A study of leather slip-on shoes used temperature sensors at five foot locations and demonstrated that both fit and leather type affected foot temperature during twenty minutes of treadmill walking; critically, this report was based on a single female subject wearing a non-athletic shoe with a collar opening that reached the midfoot[19]. Two subsequent studies examined both temperature and the greater "microclimate" of the shoe and used either seven or eight temperature monitoring sites. One study performed in seventeen young adult males looked at the effects of gait speed on temperature when subjects were wearing the same "running shoe", and showed that as speed increased then plantar foot temperature increased but dorsal foot temperature decreased[10]. Most recently, a study of ten young adult females running in "open" and "closed" versions of the same mesh athletic shoe model reported that foot temperature was greater in the "closed" versus "open" running shoes and that subjects perceived the "open" shoe more favorably, but that the temporal characteristics of foot temperature change were similar for both shoe models[20].

To date, no studies have compared females and males directly in the same protocol, nor have any addressed more distinct differences in commercially available running shoe uppers (such as mesh versus vinyl) using lengths of times that the typical runner would run. The purpose of the present study was to investigate how shoe material (mesh versus vinyl uppers) affected lateral dorsal foot temperature (LDFT) during thirty minutes of treadmill running in both females and males. It was hypothesized that higher LTFD's, greater ratings of perceived heat, and lower ratings of perceived comfort would be associated with vinyl compared to mesh.

Methods

Participants

The Drake University Institutional Review Board reviewed and approved the protocol (ID 2009-10088) before the study began. Ten adult females (20.6 ± 0.37 yrs, 168.6 ± 1.8 cm, 64.5 ± 6.8 kg) and ten adult males (21 ± 0.34 yrs, 180.3 ± 1.61 cm, 74.6 ± 2.1 kg) gave informed consent to participate. Inclusion criteria included recruiting subjects who: (1) could safely run for 33 minutes on a treadmill; (2) were a size 8 or 9 shoe (female) or a size 10, 11, 12 shoe (male); and (3) had no restricting health conditions. All subjects engaged in self-reported aerobic activity for a minimum of three sessions per week at a self-reported moderate level or greater for a minimum of 30 minutes each session, and maintained that level of physical activity during the study.

Experimental design

Subjects visited the lab on two separate occasions exactly one week apart, at the same time of day and wearing similar clothing for each trial (T-shirt and shorts) to minimize variability[21]. Procedures during the trials were identical except for the type of shoe (mesh versus vinyl). Trial order was counterbalanced. The mesh shoe for both sexes was the Puma Voltaic V (identification numbers 187346-11 for women and 187345-03 for men). We could not identify a vinyl shoe model that was manufactured for both men and women at the time of the study and instead located two models that were the most similar to each other: the Puma Cell Jago 8V1 for women (186968-01) and the Puma Cell Tolero III for men (185958-05). All shoes were marketed specifically as running shoes by the manufacturer. Subjects tied their own shoe laces[22–24]. Subjects were given a brand new pair of socks before each trial. All subjects wore Nike Performance Cotton Cushioned ankle-cut socks that differed only slightly in fiber composition between the sexes (females: 62% cotton, 34% nylon, 2% polyester, and 2% spandex; males: 69% cotton, 29% nylon, and 2% spandex);

previous research suggests these fiber composition differences are too negligible to influence the study[18].

Procedures

Shoes and socks were weighed before the beginning of each experiment and after the cool-down was over to determine sweat accumulation. Subjects were fitted with two flexible temperature probes (YSI-4600; YSI Instruments, Inc.) as described previously[4,6], one affixed to the dorsal lateral aspect of the right foot (Figure 1a), and the other in the same location but on top of the sock (Figure 1b). The temperature probes were held in place with black electrical tape and were secured to the subjects' ankles and knees before being threaded up through the waistband of their shorts or pants (Figure 1c) for safety purposes.

For each treadmill running session, subjects performed a three-minute warm-up at 75% of the speed they wanted to use for the main run, a thirty-minute run at a constant speed, and a ten-minute cool down. For subsequent time point abbreviations, WU = warm-up, R = run, and CD = cool-down. During the cool-down, subjects were seated and kept their shoes on. The treadmill model used was the Sole TT8 (Sole, Inc.). LDFT recordings were taken: every minute during the warm-up; at 2.5, 5, 7.5, 10, 15, 20, 25, and 30 minutes during the run; and every minute during the cool-down. This resulted in 24 LDFT recordings taken each trial. Subjects were allowed to drink water or sports beverages throughout the trial at any time; beverage containers were weighed before being given to subjects and after the cool-down to account for fluid consumption.

At six separate time periods throughout the study (WU 0:00, WU 3:00, R 15:00, R 30:00, CD 5:00, and CD 10:00), two 10-cm visual analogue scales[25,26] were presented to the subject to measure their perception of foot comfort and foot temperature separately[6]. Subjects drew a vertical line on the continuum to indicate their rating. The foot comfort scale ranged from "least comfortable imaginable" to "most comfortable imaginable", and the foot temperature scale ranged from "least hot imaginable" to "most hot imaginable".

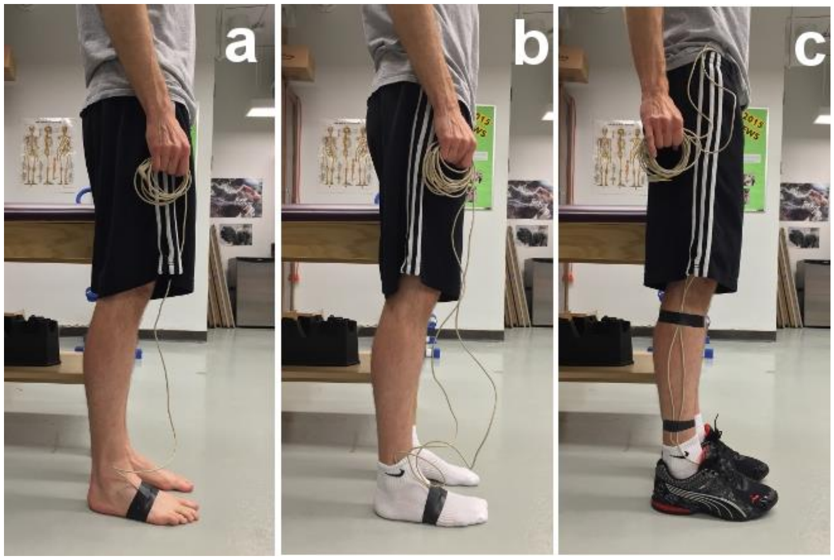

Figure 1. Thermometer attachment at (a) the skin site and (b) the sock site, with (c) cords taped along the lateral aspect of the leg and threaded up through the waistline to avoid tripping hazard.

Statistical analyses

Data was inputted into an electronic spreadsheet using Microsoft Excel and imported into SPSS Statistics v22 (IBM, Inc.). The experimental outcomes (dependent variables) were LDFT at the skin site, LDFT at the sock site, perceived foot temperature, perceived foot comfort, sock sweat accumulation, shoe sweat accumulation, and fluid consumption. Four independent variables were identified: trial order, time point, shoe type, subjects' sex. The main interests in this investigation were shoe type and subjects' sex; the effects of exercise on temperature (time point) are well documented and no effect of trial order was expected based on the counterbalanced design. Therefore, for any given dependent variable, shoe type and sex were run as a two-way ANOVA, whereas trial order and time point were run as separate one-way ANOVAs. When applicable, Pearson bivariate correlations were used to examine relationships between some of the dependent variables. Significance was defined as a p-value <0.05. Values in the figures, tables, and text are given as means $\pm$ standard deviations.

Not all data outcomes were measured with the same frequency or at the same points during the experiment, so time point comparisons differed slightly for the different outcomes. For the LDFT data, 24 time points were recorded in total; since this would have yielded an unwieldy number of comparisons, only five foot temperature differentials were analyzed as an initial exploration: during the warm-up alone (warm-up 0:00 to warm-up 3:00); during the run alone (run 0:00 to run 30:00), during the cool-down alone (cool-down 0:00 to cool-down 10:00), from the start of the warm-up to the end of the run (warm-up 0:00 to run 30:00), and from the start of the warm-up to the end of the cool-down (e.g., the entire measuring period; warm-up 0:00 to cool-down 10:00). To normalize the foot temperature data to account for between-subjects variation, temperature differentials (e.g., ΔT, the change in temperature across two time points) were calculated and analyzed instead of raw temperatures. If significant main effects were found for a factor, then the data was examined at closer resolution (finer time points). For the perceptual data, all six time points were analyzed. For the sweat accumulation, there were only pre-exercise and post-exercise values.

Sample size had been chosen based on similar previous studies[4–6,10,13,20].

Results

LTFD Readings

Raw LDFT temperatures are presented in Figure 2, whereas temperature differentials (e.g., ΔT, the change in temperature across consecutive time points) are presented in Figure 3. Figures 2 and 3 display data from eight regularly-spaced representative time points from the experiment for the purposes of summarizing the data collection period; data for all 24 time points may be found in Appendices 2 and 3. As explained in Methods, the data in Figure 3 was used for statistical analysis.

There was a significant main effect of time such that LDFT was significantly different across all of the initial five time point comparisons at both the skin and sock sites (all $p<0.001$); consequently, the analysis was rerun across finer time points. LDFT increased significantly by the first minute of exercise at both sites (both $p<0.001$), and continued to increase every time point thereafter during exercise. LDFT decreased significantly by the first minute of rest at the sock site ($p<0.001$), but not until the third minute of rest at the skin site ($p\leq0.001$).

There was no main effect for shoe type (mesh versus vinyl; ($p\geq0.179$). There was a main effect of sex for three time point comparisons: during the warm-up alone at the skin site (females 0.95 $\pm$ 0.21°; males 1.24 $\pm$ 0.5°; $p=0.028$), during the warm-up alone at the sock site (females 0.83 $\pm$ 0.54°; males 1.45 $\pm$ 0.46; $p<0.001$), and during the cool-down alone at the sock site (females 0.04 $\pm$ 0.61°; males -0.36 $\pm$ 0.5°; $p=0.039$). Given the overall lack of statistical significance across these broader time point comparisons, it did not make sense to explore trial order, shoe, or sex effects at any finer resolution.

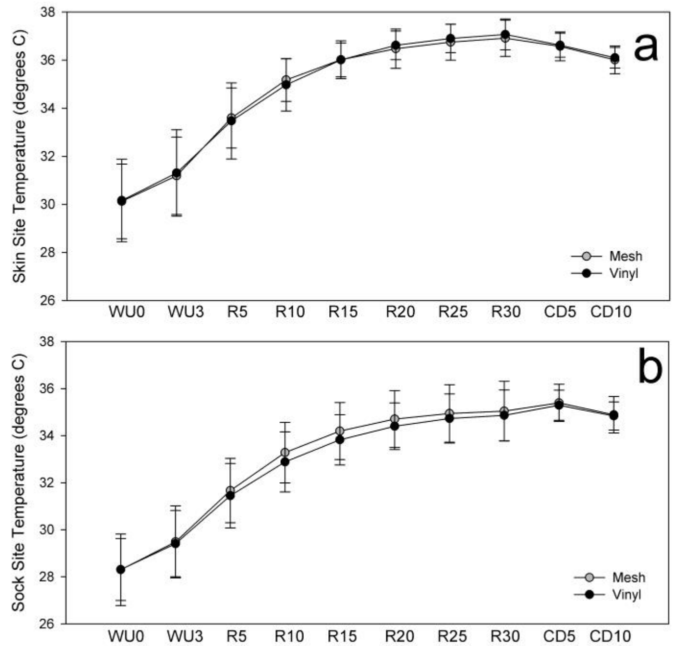

Figure 2. Raw LDFT readings in °C at representative time points for (a) the skin site and (b) the sock site. Data are expressed as mean ± standard deviation. Grey circles represent data from the mesh shoe condition whereas black circles represent data from the vinyl shoe condition. The x-axis represents time during the study, with letters indicating different stages of the protocol (WU=warm-up, R=run, CD=cool-down) and numbers indicating minutes within a stage.

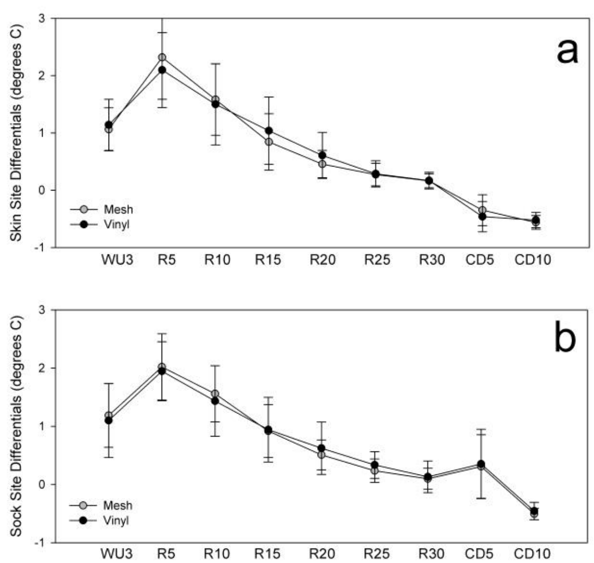

Figure 3. Temperature differentials in °C at representative time points for (a) the skin site and (b) the sock site. Data are expressed as mean ± standard deviation. Grey circles represent data from the mesh shoe condition whereas black circles represent data from the vinyl shoe condition. The x-axis represents time during the study, with letters indicating different stages of the protocol (WU=warm-up, R=run, CD=cool-down) and numbers indicating minutes within a stage.

Perceived Foot Temperature

Perceived overall foot temperature across the six time points is shown in Figure 4a. There were no main effects for sex (p=0.11). There was a significant main effect of shoe (p=0.012) such that subjects' perceived overall foot temperature was lower when wearing the mesh shoe versus the vinyl shoe (mesh 4.1 ± 2.3; vinyl 4.8 ± 2.4). Separately, there was a significant main effect of time (p<0.001); follow-up *post hoc* tests (LSD) revealed significant differences (p≤0.002) across all possible time point comparisons except for between WU 0:00 versus WU 3:00, WU 3:00 versus CD 10:00, and CD 5:00 versus CD 10:00.

Perceived Foot Comfort

Perceived foot comfort across the six time points is shown in Figure 4b. There were no main effects for sex (p=0.559). There was a significant main effect of shoe (p=0.001) such that subjects' perceived foot comfort scores were significantly higher in the mesh compared to the vinyl shoe (mesh 6.1 ± 2.2, vinyl 5.2 ± 2.3). Separately, there was a significant main effect of time (p<0.001); follow-up *post hoc* analyses revealed significant differences (p≤0.002) across all possible time point comparisons except for between WU 0:00 versus WU 3:00, WU 3:00 versus CD 10:00, and CD 5:00 versus CD 10:00. This was identical to what was observed regarding perceived foot temperature.

Sweat Accumulation

Shoe sweat accumulation was significantly greater in males than females (Table 1; p=0.008). Although shoe sweat accumulation was greater in the vinyl compared to the mesh shoes, the difference was not statistically significant (Table 1; p=0.1). *Sock* sweat accumulation was also significantly greater in males than females (Table 1; p<0.001). Although sock sweat accumulation was greater in the vinyl compared to the mesh shoes, the difference was not statistically significant (Table 1; p=0.213).

Table 1. Sweat accumulated by shoes and socks from pre- to post-exercise. Data are expressed in grams as mean ± standard deviation.

	Sock	Shoe
Female	2.7 ± 2.3*	1.5 ± 1.2*
Male	6.2 ± 5.2	2.0 ± 1.4
Mesh	4.0 ± 4.1	1.3 ± 1.2
Vinyl	4.9 ± 4.6	2.1 vs 1.3

* Significant differences (p≤0.05) between females and males.

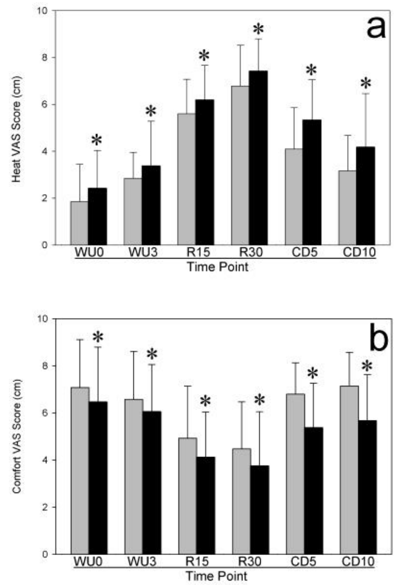

Figure 4. Perceived ratings of (a) relative foot temperature and (b) relative foot comfort as assessed by 10-cm visual analogue scales (VAS). The x-axis represents time during the study, with letters indicating different stages of the protocol (WU=warm-up, R=run, CD=cool-down) and number indicating minutes within a stage. Asterisks indicate significant differences between shoes.

<u>Fluid Consumption</u>

Fluid consumption did not differ based on shoe (mesh = 402.2 ± 228.9 g; vinyl = 409.9 ± 241.0 g; p=0.915). Although fluid consumption by males was greater than fluid consumption by females (447.7 ± 178.9 g vs 364.2 ± 273.5 g, respectively), the difference was not statistically significant (p=0.269).

<u>Correlations</u>

There was a significant, positive correlation between perceived foot temperature and LDFT at the skin site (0.287; p<0.001) as well as at the sock site (0.273; p<0.001). There was a significant, negative correlation between perceived foot temperature and perceived comfort (-0.613; p<0.001). To determine if there was a correlation between treadmill speed and LTFD, LTFD was correlated with treadmill speed at three time points: WU 3:00, R 15:00, and R 30:00. For the warm-up comparison, there was a significant, positive correlation between treadmill speed and skin site temperature (0.371; p=0.02) as well as sock site temperature (0.363; p=0.21); however, there were no significant correlations during the run.

Discussion

Two of the three initial hypotheses were supported by the findings.

<u>LDFT Outcomes</u>

The first hypothesis was that *physiological* foot temperature would be higher in the vinyl shoes compared to the mesh shoes. Data did not support the hypothesis (Figures 2 and 3)—there were no significant differences in LDFT between vinyl and mesh running shoes at any time point. These findings are consistent with a previous report from our team[4] that used similar thermometer locations but was limited to males only and only used a five-minute running bout, and the general temporal dynamics of foot temperature were consistent with a separate previous report for the same thermometer location[10]. We cannot directly compare these results to the "open"/"closed" running shoe study[20] because that report averaged the temperature readings from seven different thermometer sites around the foot. While the general temporal dynamics were similar between the present findings and that study, the other researchers reported significant differences between the "open" and "closed" shoes[20]. The most obvious explanation is the difference in the number of sites sampled (one the lateral dorsal aspect in the present study, versus seven regions in the other study). An important implication of this comparison is that foot temperature readings from the lateral dorsal aspect of the foot may not be the best representative of overall foot temperature.

One possible explanation for the lack of difference between the mesh versus the vinyl shoe is that the majority of air movement, and consequently potential heat transfer, may have occurred at the shoe collar instead of along the shoe upper, as has been suggested by the recent data supporting the "bellows hypothesis"[19,20]. In this hypothesis[19], a bellows-type action is created by the alternating compression and release of the shoe by the foot during stance and swing phases; consequently, upper material composition may be less important than ankle fit around the collar. Several different shoe sizes were available in the present study to accommodate the runners' different foot sizes, and only runners fitting the available shoe size ranges were recruited, so it is unlikely that sizing factors were a confounding factor. Subjects were allowed to tie their own laces, so it is possible that variation in lace tightness (either between subjects or even between trials of the same subject) influenced the results; however, the other studies using multiple site methods also (apparently) allowed subjects to tighten their own laces[10,20]. A future experiment could test this hypothesis by comparing foot temperature during movement in similarly laced shoes, or even better in low-top versus high-top athletic shoes. Compared to a low-top shoe, a fully laced high-top shoe that extends beyond the ankle and tightly surrounds the shank could diminish ventilation (bellows action) between the shoe interior and environment.

Perceptual Outcomes

The second hypothesis was that *perceived foot temperature* would be higher in the vinyl shoes compared to the mesh shoes, whereas the third hypothesis was that *perceived foot comfort* would be lower in the vinyl shoes compared to the mesh shoes. Data supported both hypotheses (Figure 4). Significant differences in perceived foot temperature were found between mesh and vinyl shoes at all surveyed time points, with the mesh shoes being perceived as cooler (Figure 4a). Significant differences in perceived foot temperature were also found across most time points generally such that subjects correctly sensed their foot temperature increasing during the run and decreasing during the cool-down. Similarly, significant differences in perceived footwear comfort were found across most time points such that the mesh shoes were perceived as more comfortable than the vinyl shoes (Figure 4b).

In the context of running at ambient room temperature, it appears that the foot may be able to discriminate between large changes in temperature (such as the 5°C difference from WU 3:00 to R 15:00), but not smaller changes of a couple degrees (Figure 2). Other researchers have also reported the foot can discriminate between large temperature changes at cooler environmental temperatures[8]. Future research may be able to determine the "threshold" temperature change at which the foot can perceive a difference. Discrepancies between perceived and actual foot temperature have been found previously in our lab[4,6] as well as others'[5,7]. All of these studies examined running or walking at room temperature, though they were a combination of shoe and sock studies. It is unknown whether these findings are generalizable to cooler or warmer environmental extremes.

Perception of foot microclimate more broadly has been significantly correlated with perception of other factors such as foot/shoe humidity, shock absorption, pronation control, and fit. In one report assessing several of those variables, subjects did not distinguish between characteristics, but generally rated all parameters favorably if they liked the shoes overall and unfavorably if they did not like the shoes overall[27]. In the "open"/"closed" shoe study, subjects were asked to rate several characteristics related to temperature and humidity from multiple foot sites, with the researchers concluding that 67% of a subjects' perception of "thermal comfort" specifically was associated with actual skin temperature[20]. Since this study assessed foot comfort more broadly (and not specifically "thermal comfort"), it is perhaps tenuous to compare the two studies directly; however, "comfort" ratings were lower for the "closed" shoe in that study and for the "vinyl" shoe in this study, suggesting the findings are similar. The present results are also consistent with the aforementioned pilot study[4].

Apart from the main hypotheses, we also found no significant differences in post-exercise shoe or sock sweat accumulation in relation to shoe model. These results are perhaps unsurprising. While heat transfer from the foot contributes to whole-body heat balance, its relative contribution is less than other body regions and rates of sweating do not change with exercise intensity[28]. Restricting sweat evaporation of the trunk has more profound effects on heat balance than restricting sweat accumulation at the leg[11]. Even if one shoe model had restricted sweat evaporation (and hence evaporative cooling) more than another model, the difference in heat transfer at the foot may not have significantly impacted whole-body heat balance.

Limitations

This study has several limitations. First, we measured foot temperature at only one site along the dorsal aspect of the foot. This study was conducted before several of the research papers cited herein were available, when this area of research was still newer. Now, different foot regions are known to exhibit different foot temperatures during exercise[10,20]; thus, findings may have been different had a different site been selected or if multiple sites had been jointly monitored. In a similar way, different foot regions may have different sweating rates[12], and sweat production findings may have been different if sweat was collected from discrete sites versus from the foot overall. Second, subjects could see the shoes during the experiment. Their prior experiences, and consequently *a priori* assumptions of shoe properties, may have influenced their subjective scores. Third, our study included only young adult men and women that could fit into common shoe sizes for their demographic. Fourth and finally, the present study was performed at room temperature, and it is unclear whether the findings would be generalizable to other running conditions, such as extreme heat or cold[29].

Conclusions

The main finding from this study was that LDFT was not influenced by whether the running shoe upper was constructed from mesh or vinyl, although subjects perceived differences in foot temperature—and also comfort—between the two shoe models. Subsequent studies have indicated broader sampling of the foot may be necessary to determine representative foot temperature readings. Nevertheless, findings from this study were largely consistent with other published research and suggest that the foot may have limited abilities to consistently and correctly perceive foot temperature changes less than 5°C.

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Appendices

Appendix 1. Differences in experimental design between the sock studies.

Reference	Sock Variable	Shoes	Population	Exercise	Conclusions
4	3 models: cotton, polyester/ cotton blend, polyester	Same*	16 young adult males	3 × 5 min treadmill running at self-selected pace; 20°C ambient room temperature	No differences in actual foot temperature; polyester sock perceived as cooler
7	3 running sock and 3 hiking sock models of differing compositions	Different†	6 adult male runners + 5 adult male hikers	3 × 40 min treadmill running at 10 km/hr OR 3 × 40 min walking at 5 km/h with 5% incline wearing a 5 kg backpack; 25°C ambient room temperature	Foot temperature was similar regardless of sock; subjects perceived cotton-containing socks as warmer than socks lacking cotton
14	2 models: polypropylene and wool/ polypropylene blend	Same‡	12 young adult males	3 × 30 min treadmill walking at 5 km/h; 17°C ambient room temperature	Foot temperature was lower at the third metatarsal with polypropylene, but higher at the distal anterior end of the tibia with wool/polypropylene blend
15	2 models: polypropylene and wool/polypropylene blend	Same‡	32-37 young adult males	2? × 1 day of military instruction, drills, and 6.5 km march; 8.5-13.5°C environmental temperature	Wool/polypropylene was perceived as cooler
13	5 models (undescribed)	Different†	19 subjects	5 × 6000m run outdoors at self-selected pace; 26.5°C environmental temperature	2 models had resulted in higher foot temperatures at the end of the run
17	2 models: acrylic and cotton	Different†	60 runners of varying age, sex, and experience	4 × 5-10 running trials ranging from 45-180 min at self-selected pace over a 10-30 d period	Possible differences in perceived foot temperature (contingent on statistical model chosen)
16	2 models: acrylic and cotton	Different†	50 runners of varying age, sex, and experience	2 × 10 running trials ranging from 45-180 min at self-selected pace over a 10-30 d period	No differences in perceived foot temperature
5	2 models: cotton/ nylon and cotton/ polypropylene/ nylon "ergonomic" sock	Different†	8 female + 8 male young adults	2 × 30 min treadmill running at 12 km/h; 21°C ambient room temperature	No differences in actual or perceived foot temperature
6	2 models: cotton and olefin	Same*	12 young adult males	2 × 30 min treadmill running at self-selected pace; 20°C ambient room temperature	Lower foot temperatures at one site for olefin sock; no differences in perceived temperature

Symbols under the "Shoe" column: * = all subjects ran in the same running shoe model as supplied by the laboratory; † = subjects ran in their own shoes; ‡ =all subjects wore the same military-issued combat boots.

Appendix 2. Raw LDFT readings for all 24 time points from both the skin and sock thermometer sites. Data are expressed in °C as mean ± standard deviation.

	Skin Site		Sock Site	
	Mesh	Vinyl	Mesh	Vinyl
Warm-Up 0 min	30.1 ± 1.6	30.2 ± 1.7	28.3 ± 1.5	28.3 ± 1.3
Warm-Up 1 min	30.4 ± 1.6	30.5 ± 1.8	28.7 ± 1.5	28.7 ± 1.4
Warm-Up 2 min	30.7 ± 1.6	30.8 ± 1.8	29.1 ± 1.5	29.1 ± 1.4
Warm-Up 3 min§	31.2 ± 1.6	31.3 ± 1.8	29.5 ± 1.5	29.4 ± 1.4
Run 0 min§	31.3 ± 1.6	31.4 ± 1.8	29.6 ± 1.6	29.5 ± 1.5
Run 2.5 min	32.5 ± 1.5	32.5 ± 1.7	30.6 ± 1.5	30.5 ± 1.5
Run 5 min	33.6 ± 1.3	33.5 ± 1.6	31.7 ± 1.4	31.5 ± 1.4
Run 7.5 min	34.5 ± 1.0	34.3 ± 1.3	32.6 ± 1.3	32.2 ± 1.4
Run 10 min	35.2 ± 0.9	35.0 ± 1.1	33.3 ± 1.3	32.3 ± 1.3
Run 15 min	36.0 ± 0.8	36.0 ± 0.7	34.2 ± 1.2	33.8 ± 1.1
Run 20 min	36.5 ± 0.8	36.6 ± 0.6	34.7 ± 1.2	34.4 ± 1.0
Run 25 min	36.8 ± 0.8	36.9 ± 0.6	34.9 ± 1.2	34.7 ± 1.0
Run 30 min¶	36.9 ± 0.8	37.1 ± 0.6	35.0 ± 1.3	34.9 ± 1.1
Cool-Down 0 min¶	36.9 ± 0.7	37.1 ± 0.7	35.1 ± 1.2	34.9 ± 1.1
Cool-Down 1 min	37.0 ± 0.7	37.0 ± 0.6	35.3 ± 1.0	35.2 ± 0.9
Cool-Down 2 min	36.9 ± 0.6	37.0 ± 0.6	35.4 ± 0.8	35.3 ± 0.8
Cool-Down 3 min	36.8 ± 0.6	36.9 ± 0.5	35.5 ± 0.8	35.4 ± 0.7
Cool-Down 4 min	36.7 ± 0.6	36.8 ± 0.5	35.5 ± 0.8	35.4 ± 0.7
Cool-Down 5 min	36.6 ± 0.6	36.6 ± 0.5	35.4 ± 0.8	35.3 ± 0.6
Cool-Down 6 min	36.5 ± 0.6	36.5 ± 0.5	35.3 ± 0.8	35.2 ± 0.6
Cool-Down 7 min	36.3 ± 0.6	36.4 ± 0.5	35.2 ± 0.8	35.1 ± 0.6
Cool-Down 8 min	36.2 ± 0.6	36.3 ± 0.5	35.1 ± 0.8	35.0 ± 0.6
Cool-Down 9 min	36.1 ± 0.6	36.2 ± 0.4	35.0 ± 0.8	34.9 ± 0.6
Cool-Down 10 min	36.0 ± 0.6	36.1 ± 0.4	34.9 ± 0.8	34.8 ± 0.6

Section sign (§) and pilcrow (¶) symbols indicate adjacent time points that represent "transitional" stages and should be redundant; as the warm-up transitioned into the run with a simple increase in treadmill speed, and as the run transitioned into the cool-down with the stopping of the treadmill and a 3-m walk to a nearby chair, no differences were expected between these two readings. Each pair was taken out of an "abundance of caution." Given their redundancy, neither "Run 0 min" nor "Cool-Down 0 min" was considered during analysis.

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Appendix 3. Temperature differentials for all 24 time points from both the skin and sock thermometer sites. Data are expressed in °C as mean ± standard deviation and were calculated as ΔT, or the change in temperature across consecutive time points.

	Skin Site		Sock Site	
	Mesh	Vinyl	Mesh	Vinyl
Warm-Up 0 min	N/A	N/A	N/A	N/A
Warm-Up 1 min	0.3 ± 0.2	0.3 ± 0.2	0.4 ± 0.3	0.4 ± 0.3
Warm-Up 2 min	0.3 ± 0.2	0.4 ± 0.2	0.4 ± 0.2	0.3 ± 0.3
Warm-Up 3 min§	0.4 ± 0.2	0.5 ± 0.2	0.4 ± 0.2	0.3 ± 0.2
Run 0 min§	N/A	N/A	N/A	N/A
Run 2.5 min	1.2 ± 0.4	1.2 ± 0.4	1.0 ± 0.3	1.0 ± 0.4
Run 5 min	1.1 ± 0.2	1.0 ± 0.3	1.1 ± 0.3	1.0 ± 0.3
Run 7.5 min	0.9 ± 0.4	0.8 ± 0.4	0.9 ± 0.3	0.8 ± 0.3
Run 10 min	0.7 ± 0.3	0.7 ± 0.4	0.7 ± 0.2	0.7 ± 0.3
Run 15 min	0.8 ± 0.5	1.0 ± 0.6	0.9 ± 0.5	0.9 ± 0.6
Run 20 min	0.5 ± 0.2	0.6 ± 0.4	0.5 ± 0.3	0.6 ± 0.5
Run 25 min	0.3 ± 0.2	0.3 ± 0.2	0.2 ± 0.2	0.3 ± 0.2
Run 30 min¶	0.2 ± 0.1	0.2 ± 0.1	0.1 ± 0.2	0.1 ± 0.3
Cool-Down 0 min¶	N/A	N/A	N/A	N/A
Cool-Down 1 min	0.0 ± 0.2	0.0 ± 0.1	0.2 ± 0.3	0.2 ± 0.3
Cool-Down 2 min	0.0 ± 0.1	-0.1 ± 0.1	0.1 ± 0.2	0.2 ± 0.2
Cool-Down 3 min	-0.1 ± 0.1	-0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Cool-Down 4 min	-0.1 ± 0.1	-0.1 ± 0.0	0.0 ± 0.1	0.0 ± 0.1
Cool-Down 5 min	-0.1 ± 0.0	-0.1 ± 0.0	-0.1 ± 0.1	-0.1 ± 0.0
Cool-Down 6 min	-0.1 ± 0.0	-0.1 ± 0.0	-0.1 ± 0.0	-0.1 ± 0.0
Cool-Down 7 min	-0.1 ± 0.0	-0.1 ± 0.0	-0.1 ± 0.0	-0.1 ± 0.0
Cool-Down 8 min	-0.1 ± 0.1	-0.1 ± 0.0	-0.1 ± 0.0	-0.1 ± 0.0
Cool-Down 9 min	-0.1 ± 0.1	-0.1 ± 0.0	-0.1 ± 0.0	-0.1 ± 0.0
Cool-Down 10 min	-0.1 ± 0.0	-0.1 ± 0.0	-0.1 ± 0.0	-0.1 ± 0.0

Section sign (§) and pilcrow (¶) symbols indicate adjacent time points that represent "transitional" stages and should be redundant; as the warm-up transitioned into the run with a simple increase in treadmill speed, and as the run transitioned into the cool-down with the stopping of the treadmill and a 3-m walk to a nearby chair, no differences were expected between these two readings. Each pair was taken out of an "abundance of caution." Given their redundancy, neither "Run 0 min" nor "Cool-Down 0 min" was considered during analysis. This table shows every individual time point whereas Figure 3 shows "snapshots" encompassing a summary of several time points; therefore, the values in Figure 3 appear larger but represent the same data