Body Mapping of Sweating Patterns in Athletes: A Sex Comparison

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Abstract

Purpose: Limited regional sweat data are available for females, with only a small number of sites measured across the body. Similarly, sex differences in sweating typically concentrate on whole body sweat loss, with limited data on regional sweat rates (RSR). **Methods:** A modified absorbent technique was used to collect sweat at two exercise intensities (60% (I1) and 75% (I2) $\dot{V}O_{2\ max}$) in 13 aerobically trained females (21±1 yrs, 59±7 kg, 1.64±0.1 m^2, 18±4% body fat, 59.5±10 $ml^{-1}.min^{-1}.kg^{-1}$ VO_{2max}) in moderately warm conditions (25°C, 45% rh, 2 $m.s^{-1}$ air velocity). Female data were compared to 9 aerobically trained males (23±3 yrs, 74±5 kg, 1.92±0.1 m^2, 11±5% body fat, 70.2±13 $ml^{-1}.min^{-1}.kg^{-1}$ VO_{2max}) tested under the same experimental conditions. **Results:** Female RSR at I1 were highest at the central upper back, heels, dorsal foot, and between the breasts, with values of 223, 161, 139 and 139 $g.m^{-2}.h^{-1}$, respectively. Lowest values were over the breasts and at the mid and lower outer (lateral) back with values below 16 $g.m^{-2}.h^{-1}$. Similarly at I2 the central upper back and bra triangle showed some of the highest RSR in addition to the lower back, showing values of 723, 470, and 333 $g.m^{-2}.h^{-1}$, respectively. Regions of the breasts and the palms had the lowest RSR at I2 with values below 82 $g.m^{-2}.h^{-1}$, respectively. Significantly greater absolute GSL and thus RSR were observed in males compared to females at both exercise intensities. For the same metabolic heat production (comparing male I1 vs. female I2) both absolute and normalised RSR data showed a significant region and sex interaction ($p < 0.001$), with a greater distribution towards the arms and hands in females compared to males. **Conclusions:** Despite some differences in distribution, both sexes showed some of the highest RSR on the central upper back and the lowest towards the extremities. No correlation was observed between local skin temperature and RSR, failing to

explain the RSR variation observed. These data have important applications for sex specific clothing design, thermophysiological modelling, and thermal manikin design.

Keywords: sweating, metabolic rate, sex, sweat mapping, regional

Introduction

Paragraph 1 The majority of thermoregulatory research available focuses on males rather than females and emphasises core temperature and whole body sweat loss. Limited research is available on females, with a sparsity of information on regional sweat rates. Historically, regional sweat rates have been measured over a very limited number of sites or studies have used qualitative methods to assess sweating over large surface areas (Kuno, 1956). More recently, several studies have measured regional sweat rates on multiple body regions (12, 30-32, 39, 40, 42), however, these studies used only males or reported combined data from both sexes. The only data currently available on females were limited to torso sweat rates (22), which identified significant regional variation between zones. The first study measuring regional sweat rates over almost the whole body surface area in males was recently published by Smith and Havenith (38), identifying both significant inter and intra-regional variation in sweating. To the knowledge of the authors no study has attempted to measure regional sweat rates simultaneously over large skin surface areas for females.

Considerable debate surrounds sex differences in thermoregulation. Traditionally, women (testing a population average) are considered less effective in regulating body temperature than males in dry heat (36), with maintenance of a significantly lower sweat rate compared to men, and a substantially higher rectal temperature (7, 13, 14, 36, 37). A more pronounced delay in sweat onset has also been noted in women, attributed in part to a lower body water content (20), and potential effects of menstruation (25). Observations of sex-related differences in sweat rate, sweat thresholds (25), sweat gland size and distribution (4, 5, 25) have contributed to the opinion that females generally sweat less than males. Conversely, several studies have observed that sex differences in thermoregulation cease to be significant upon matching subjects or correcting for anthropometric, acclimatisation, and fitness parameters (2, 3, 14, 15, 23, 24). Such disagreement in the literature must be viewed with careful consideration of the experimental design, measurement technique and subject characteristics. Individual characteristics play a major role in thermoregulatory responses to heat stress (23, 24) and are thought to explain a substantial part of response variation observed (17). More recently, however, studies supporting the existence of sex-differences per se in thermoregulation have emerged; Madeira and colleagues (33) have demonstrated a greater pilocarpine-induced sweating responses in males compared to females when groups were matched for $\dot{V}O_{2\ peak}$. Aerobic capacity is known to enhance sudomotor response to pilocarpine in males (8), which may partially explain sex differences in local sweating in studies using unmatched groups. In addition, Gagnon et al. (19) observed lower evaporative heat loss and thermosensitivity in females despite a fixed absolute metabolic heat production and matching of physical characteristics between sexes.

This is of particular importance when considering fixed absolute versus relative work rates, whereby sex differences may be artificially created. During absolute work rate protocols, results may be confounded between groups if unmatched for $\dot{V}O_{2\ max}$ and/or body composition. Alternatively, when relative work rates are used differences in absolute work rates and thus metabolic heat production may arise between sexes (18, 21). Group 'matching' is therefore important to consider and in doing so either comparing 'average' individuals from each population or, to match $\dot{V}O_{2\ max,}$ accepting that this is an unrepresentative sample from one population. With this in mind, the present study has taken an applied approach in comparing thermoregulatory responses between sexes in which the groups were selected for similar training and athletic performance levels (elite to sub-elite athletes) and were therefore not matched for physical characteristics. For exercise load it was decided to use relative work rates which represent training and competition practice.

Paragraph 2 The aims of the present study were 1) to produce a whole body sweat map of aerobically trained females during mild exercise-induced hyperthermia, and 2) compare these data to previously published body maps of sweating in aerobically trained males produced in our laboratory under the same experimental conditions (38). It was hypothesised that, similar to males, significant regional variation in sweat rate would be observed within the female group, with consistent patterns of variation between participants. It was further hypothesised that females would sweat significantly less than males due to a lower absolute metabolic heat production when exercising at a fixed relative workload, arising from a lower absolute aerobic capacity. Similar patterns of distribution of sweating were expected between sexes.

Methods

Participants

Paragraph 3 Thirteen female unacclimated, aerobically trained, elite to sub-elite runners participated in whole body sweat mapping. All experimental procedures were approved by the Loughborough University Ethical Committee and were fully explained to the participants before obtaining informed written consent and completion of a healthscreen questionnaire.

Pre-Test Session

Paragraph 4 Participants attended the Environmental Ergonomics Research Centre for anthropometric measurements of height, mass, and body dimensions used for the calculation of body surface area (9) and absorbent pad sizes. Skinfolds were taken using a 4 point calliper method (26) specific to female athletes for calculation of body fat percentage. Aerobic fitness level, expressed as maximal oxygen uptake ($\dot{V}O_{2\ max}$), was calculated from a sub-maximal fitness test based on the Åstrand-Ryhming method (1). The test was conducted at an ambient temperature of 18°C to prevent thermal stress and comprised of four exercise intensities running on a treadmill (h/p/cosmos mercury 4.0 h/p/cosmos sports & medical gmbh, Nussdorf-Traunstein, Germany) each lasting five minutes. Estimation of $\dot{V}O_{2\ max}$ was based upon the linear relationship between heart rate and work rate (work rate based upon treadmill speed and angle (10).

Sweat Pad Preparation and Application

Paragraph 5 Regional sweat rates (RSRs) were determined using the method developed in our laboratory (12, 22, 38, 39) by applying absorbent material directly to the skin for a short, predefined period of time (5 minutes). Two sets of absorbent pads were produced for each participant based on the anthropometric data (see online text, Supplemental Digital Content 1 (SDC-1) for details of pad sizing). Pads were weighed (Sartorius YACOILA, Sartorius AG, Goettingen, Germany. Precision 0.01g) inside individually labelled airtight bags, in which they were stored until testing. A total of 78 pads were used to produce a whole body sweat map for each exercise intensity (see Figure 1. of online Supplemental Digital Content 2 (SDC-2) for sweat map pad locations). Pads were attached to custom sized plastic sheeting for fast application to the body and to prevent the evaporation of sweat during the test periods. The pads were kept in place against the skin using a stretch long sleeve t-shirt and trousers. For the breast area pads were attached inside a sports bra. On the feet, pads were secured in place on the ankles and dorsal surface of the foot inside 100% cotton socks which were also used to collect sweat from the top of the foot. Plastic stretch socks were worn on top to prevent evaporation of sweat from the cotton socks during the measurement period. Similarly, 100% cotton gloves were worn to collect sweat on the hands, with small incisions made at the base of each finger to prevent the migration of sweat between regions, while maintaining their structural integrity during the test. Latex gloves were worn over the cotton gloves during the measurement period to secure the gloves in place against the skin and prevent sweat evaporation.

Experimental protocol

Paragraph 6 Experimental sessions were conducted in a climate controlled room at 25.7 ± 0.4°C, 45 ± 7% relative humidity, and a 2 m.s^{-1} frontal air velocity. Data were obtained in three identical experimental sessions per participant, with approximately one third of the skin surface area covered in each test, thus allowing enough exposed skin for thermoregulation. The three sessions focused on 1) torso/upper body (UB), 2) legs, and 3) arms, hands, buttocks, and feet (AHBF). Testing sequence was balanced to prevent any order effect and performed at the same time of day to minimise circadian variation. Menstrual cycle phase was not controlled for during experimental sessions; participants were tested over a wide range of the menstrual cycle, providing a representative sample of menses state in the results.

Paragraph 7 On arrival to the laboratory participants were provided with shorts and t-shirt and then weighed. Infra-red images (IRI; Thermacam B2, FLIR Systems Ltd., West Malling, Kent, UK) of the nude, dried, skin were taken prior to testing, before and after each pad application, and immediately after testing to monitor T_{sk}. Resting heart rate (HR) was recorded before participants warmed up, with HR monitored throughout the experiment at 15 second intervals. T_{core} was measured using a VitalSense Integrated Physiological Monitoring System (Mini Mitter Company, Inc. Bend, Oregon, USA). Participants swallowed a CorTemp™ ingestible temperature pill 5 hours before testing. Throughout the experiment the VitalSense monitor wirelessly tracked and recorded T_{core} four times per minute. Participants ran for a total of 60 minutes involving two exercise intensities of 30 minutes each on the treadmill with an incline of 1%. The target HR was 125-135 and 150-160 beats per minute (bpm) for intensity 1 (I1) and intensity 2 (I2), respectively, in order to control workload at the targets of 60% and 75% of $\dot{V}O_2$

$_{max}$. Exercise intensities were not separated by a break; however, subjects were required to step off the treadmill for all measurements and pad application/removal (approximately 3 minutes). Participants removed their clothing and towelled their skin dry immediately prior to pad application to ensure only sweat produced during the sample period was collected. All of the pads had an impermeable backing to prevent evaporation. Sweat samples were taken during the last 5 minutes of each exercise intensity at 30 minutes and 60 minutes, during which time the participants returned to the treadmill donning the absorbent pads. Immediately following the sample periods the pads were quickly returned to their airtight bags and sealed. The participants could drink water freely during the experiment, which was recorded, in order to prevent dehydration. Following the 60 minute run, final measurements of core temperature, skin temperature and body weight were recorded. All pads were re-weighed inside their sealed bags. The cotton glove and sock segments could not be individually weighed before testing as they were not yet separated from each other. Immediately following sweat collection, specific sections of the gloves and socks were dissected and placed in individually labelled airtight bags. The post-test wet weight of each sample was recorded before being dried out in a thermal chamber at 30°C, 50% rh for 24 hours then re-weighed to obtain the 'dry' (pre-test) weight. The surface area of each pad was calculated from the dry weight of each pad and the weight per unit of surface area of the material. Local sweat rate was calculated in grams per meter square of body surface area per hour ($g.m^{-2}.h^{-1}$) using the weight change of the pad, the pad surface area, and duration of application to the skin.

Analysis

Paragraph 8 As data from the different experimental sessions were to be combined in a whole body sweat map, and as sweat rates may differ, even between identical sessions for an individual, it was decided to correct individual session data in line with the session's gross sweat loss (GSL) value. Data for each individual were standardised towards the mean GSL over all three sessions for that individual. All corrections work on the assumption that within each work load there is a relation between regional and GSL for an individual.

GSL was calculated based on the weight change of each participant across each test period, adjusted for fluid intake. Corrections were made for respiratory and metabolic mass losses. Evaporative loss from respiration (E_{res}, Watts) was calculated using equation [1], based upon work described by Livingstone et al. (29):

$$E_{res} = 1.27 \cdot 10^{-3} \cdot M(59.34 + 0.53 \cdot T_a - 11.69 \cdot P_a) \qquad [1]$$

And converted into mass loss (g):

$$Mass\ Loss = E_{res} \cdot t \cdot \frac{1}{2430} \qquad [2]$$

Where;

E_{res} evaporative loss from respiration (W)

M metabolic rate (W)

T_a air temperature (ºC)

t time: duration of intensity or experiment (s)

2430, latent heat of evaporation of 1 gram of water ($J.g^{-1}$)

Metabolic mass loss (g) was calculated based upon Kerslake (27):

$$Metabolic\ mass\ loss = \left(\frac{\dot{V}o_2(44 \cdot RQ - 32)}{22.4}\right) \cdot t \qquad [3]$$

Where;

$\dot{V}o_2$ rate of oxygen consumption (L.min^{-1})

RQ respiratory quotient (ND)

t time (s)

The respiratory quotient (RQ) was taken as 0.85 for intensity 1 and 1.00 for intensity 2 (34).

Sweating sensitivity for each segment (i) was calculated as:

$$Gain_{1,i} = \frac{\text{Sweat rate increase Intensity 1}}{\text{Core Temperature increase Intensity 1}} \qquad [4]$$

$$Gain_{2,i} = \frac{\text{Sweat Rate Intensity 2 - Sweat Rate Intensity 1}}{\text{Core Temperature increase Intensity 2}} \qquad [5]$$

Finally, overall sweat sensitivity was calculated for comparison with literature (30-32) as:

$$Overall\ Gain_i = \frac{\text{Sweat Rate Increase over Experiment}}{\text{Core Temperature Increase over Experiment}} \qquad [6]$$

Paragraph 9 Paired samples t-tests were performed both with and without Bonferroni correction to analyse right-left differences in sweat rate and changes with exercise intensity. A one-way repeated measures ANOVA was performed to analyse regional differences within each intensity, presented both with and without Bonferroni correction for post-hoc comparisons. Both values are presented firstly due to the exploratory nature of the study and secondly due to the large number of zones studied compared to any earlier study (6, 35). This makes the Bonferroni correction very stringent and zones that would show significance in a smaller study will struggle to reach significance here. For RSR comparison between sexes, a two way repeated measures ANOVA was performed with sex (between subject factor), region, and sex-region interaction as factors. To allow direct comparison of the upper chest between sexes despite the use of differing pads, the upper chest (3 pads) in the males and the upper chest and bra pads (11 pads) in the females were area weighted to produce a single 'upper chest' sweat rate value for each sex.

Paragraph 10 To allow standardisation of sweat data over participants and for the easy identification of 'higher' and 'lower than average' sweat regions regardless of absolute sweat rates, RSRs were normalised for the area weighted sweat rate of all zones. The same analysis was performed on the normalised regional sweat data as described above for the absolute data. Pearson's correlation coefficient was calculated to assess correlations between RSRs and regional $T_{sk,}$ and RSRs and GSL. Finally, it was decided that it would be more relevant to graphically show results for the 'average sweater' (the median) rather than the 'average amount of sweat produced' (the mean), as the latter can be affected more easily by outliers, i.e. extreme sweaters. In tables, both values are presented to provide insight into the data distribution.

Male data presented in the present paper have been reported previously (38) and are in part included here to allow comparison with the female data.

Results

Participant Characteristics

Paragraph 11 Female subjects were significantly shorter (female 165 ± 8 cm vs. male 179 ± 4, $p < 0.001$), lighter (59 ± 7 vs. 74 ± 5 kg, $p < 0.001$) , had a smaller surface area (1.64 ± 0.10 vs. 1.92 ± 0.10 m^2, $p < 0.001$) , and showed a higher body fat percentage than males (18 ± 4 vs. 11 ± 5 %, $p<0.01$). Although age was significantly different between groups (female 21 ± 1 vs. male 23 ± 3 yrs, $p=0.047$) this was not biologically relevant. Females had a significantly lower $\dot{V}O_{2\,max}$ (59.5 ± 10 vs. 70.2 ± 13 $ml.kg^{-1}.min^{-1}$, $p<0.05$) with a value 85% that of the trained males. When based on fat free mass females had a $\dot{V}O_{2max}$ 92% that of males (female 78.9 vs. male 72.6 $ml.kg^{-1}.min^{-1}$).

Core Temperature, Work Rate, and Heart Rate

Paragraph 12 *Female Data:* Baseline data were taken as the temperature and HR recorded immediately before commencing I1. Reported I1 and I2 data were the mean values over the final 5 minutes of each intensity. T_{core} increased significantly from 37.29 ± 0.29°C at baseline to 37.83 ± 0.19°C at I1 (BL to I1 ΔT_{core} = 0.54 ± 0.21°C, $p<0.001$), and to 38.06 ± 0.24°C at I2 ($\Delta T_{core;}$ BL to I2 = 0.77 ± 0.35°C, $p<0.001$, I1 to I2 = 0.23 ± 0.25°C, $p<0.01$). HR increased significantly from 66 ± 13 bpm at baseline to 134 ± 3 at I1 ($p<0.001$), and to 157 ± 3 ($p<0.001$) at I2, reflecting relative work rates of 61 ± 7 and 72 ± 11%$\dot{V}O_{2\,max}$ for I1 and I2, respectively.

Paragraph 13 *Sex Comparison:* No differences in HR were present between groups for either exercise intensity, however, running speed ($km.h^{-1}$) was significantly higher in males compared to females (I1 10.4 ± 2.0 vs. 8.5 ± 1.7, $p<0.05$; I2 13.6 ± 2.2 vs. 10.5 ± 1.7, $p<0.01$). Males showed a lower resting T_{core} than females (male 36.93 ± 0.39°C, $p<0.05$) but no sex difference was present at the end of either exercise intensity (Male I1 = 37.68 ± 0.45°C, I2 = 38.06 ± 0.44°C). ΔT_{core} were significant over both exercise intensities (Male ΔT_{core}; BL to I1 = 0.76 ± 0.18°C, I1 to I2 = 0.45 ± 0.30°C, $p<0.001$) in both sexes, with the rise being significantly greater in males from BL to I1, reflecting the lower resting T_{core} ($p<0.05$).

Gross Sweat Loss

Paragraph 14 *Female data:* Substantial variation in GSL was observed both within (between sessions) and between participants. The mean GSL of all sweat mapping experiments was 272 ± 103 $g.m^{-2}.h^{-1}$, with mean values for upper body/torso (UB), legs, and arms, hands, buttocks and feet (AHBF) sessions of 300 ± 113, 268 ± 95, and 246 ± 101 $g.m^{-2}.h^{-1}$, respectively. The mean surface areas covered in each experiment were 0.49, 0.45, and 0.33 m^2 for the AHGF, legs, and UB experiments, respectively, totalling 1.28 m^2. The percentage of body coverage was 30.1%, 27.7%, and 20.2% over the three experiments, totalling 78% of the whole body. GSL increased significantly with exercise intensity ($p<0.001$) from 168 ± 81 to 410 ± 144 $g.m^{-2}.h^{-1}$ and correlated positively with $\dot{V}O_{2\ max}$ ($r = 0.71$, $p<0.01$) and for individual work intensities (Figure 1) GSL ($g.h^{-1}$) correlated positively with metabolic rate (W; I1 $r = 0.89$, $p<0.001$; I2 $r = 0.87$, $p<0.05$) with no significant difference present between the gradient of regression lines for each exercise intensity.

Paragraph 15 *Sex comparison:* Males showed significantly higher GSL compared to females both during each exercise intensity and overall (male GSL: I1 364 ± 84, I2 657 ± 119 $g.m^{-2}.h^{-1}$, overall 458 ± 115 $g.m^{-2}.h^{-1}$; male vs. female GSL all $p<0.001$). When GSL was plotted against $\dot{V}$

$O_{2\ max}$, no significant differences between the gradient of the regression lines or the intercepts were present between sexes. Metabolic heat production was significantly greater in males than females expressed in absolute terms (Figure 1: male I1 993 ± 185 W, I2 1335 ± 259 W, both $p < 0.001$), but only at I2 when expressed as a function of surface area (male I1 519 ± 103 $W.m^{-2}$, $p = 0.081$; I2 697 ± 137 $W.m^{-2}$, $p < 0.01$).

Regional Sweat Rates

Paragraph 16 *Female Data:* RSR data were grouped for corresponding right and left zones since only one zone showed a bilateral difference. Median grouped data for all participants are illustrated for both exercise intensities in Figure 2. The pads illustrated in grey, located below the anterior and posterior neck and at the axilla, acted to absorb excess sweat which might otherwise have dripped from these areas and thus preventing it from being absorbed by adjacent pads. These extra pads were discarded following sweat collection and were not used in sweat mapping calculations. The highest sweat rates observed at I1 were at the central upper back, heels, dorsal foot, and between the breasts, with values of 223, 161, 139, and 139 $g.m^{-2}.h^{-1}$, respectively. Sweat rate increased at all regions with increasing exercise intensity, with exception of the feet, ankles, and the lateral lower breast (Table 1). At I2 the central upper back and the area between the breasts showed the highest sweat rates with values of 723 and 470 $g.m^{-2}.h^{-1}$, compared to significantly lower values on the breasts and towards the extremities. Detailed comparisons of all absolute regional sweat rates within each exercise intensity may be viewed in the Supplemental Digital Content 3 (SDC-3, Tables 1-4).‘Higher’ and ‘lower than average’ sweat rates may easily be identified using normalised regional sweat rate data, illustrated in Figure 3. Regions with sweat rate ratios significantly different from average (=1) are denoted in Table 1 by grey shading in the ratio column. A comparison of normalised ratio data between exercise intensities indicated little change in distribution between I1 and I2, with exception to a significant decrease in distribution towards the feet and shoulders and an increase towards the breasts at the higher exercise intensity.

Paragraph 18 *Sex comparison:* Regional absolute and normalised sweat data for male athletes (adapted from Smith and Havenith (38)) is presented in Figure 4. Absolute and normalised data comparisons between sexes are presented both with and without Bonferroni correction in Table 2. As expected, males showed significantly greater absolute local sweat rates compared to females at both exercise intensities, with exception of areas of the hands and feet at I1 and only the thumbs and dorsal hand at I2. Both sexes did exhibit similarities in regional sweat rates, showing 1) greater sweat rates on the anterior compared to the posterior torso, 2) a medial to lateral decrease in sweat rates across the torso, 3) the greatest sweat rates on the central and lower back (with exception to the bra triangle in females at I2), and 4) the lowest sweat rates towards the extremities. Normalised ratio data (Figure 3. vs. Figure 4b) indicated a significantly higher distribution of sweat towards the torso in males, and females showing a significantly higher distribution towards the hands and feet compared to males at both exercise intensities.

Since no significant difference in absolute metabolic rate was present between sexes for male I1 compared to female I2 a comparison of absolute and normalised data between sexes was performed for these data (Table 2). GSL do not differ significantly between males at I1 compared to females I2 when compared in absolute terms (male 699 ± 157 vs. female 685 ± 260 $g.h^{-1}$, $p = 0.887$), nor when normalised for body surface area (365 ± 84 vs. 410 ± 131 $g.m^{-2}.h^{-1}$, p

= 0.379). Absolute RSR remained significantly higher in males compared to females on the torso, legs, and areas of the feet, representing 17 of the 34 regions compared. Despite significantly greater sweat rates in males, regions of high and low sweating were similar between sexes. A significant region-sex interaction for both I1 and I2 normalised data ($p<0.001$) did however indicate some differences in distribution. Fewer differences were present in relative sweat distribution compared to absolute data, with the main exception being significantly greater ratio values for the arms and hands in females compared to males, with significance present at 9 out of the 34 regions compared.

Skin Temperature

Paragraph 19 *Female Data:* Regional T_{sk} data were right and left grouped due to only five regions out of the 48 measured showing significant bilateral differences, and no significant differences following Bonferroni correction. T_{sk} increased from baseline to I1 at only the feet and ankles (uncorrected: heels, soles and dorsal foot $p < 0.001$, ankles $p < 0.05$. Corrected: heels and soles $p < 0.001$, dorsal foot $p < 0.01$), reflecting their low baseline temperatures. The lowest baseline T_{sk} of 26.5°C was observed at the heels compared to the highest value of 34.0°C at the anterior upper chest and medial upper back. Interestingly, the mean increase in T_{sk} of all regions from pre to post pad application was 1.1°C for both I1 and I2, reflecting the impact of the measurement technique itself on T_{sk}.

Paragraph 20 A within-participant analysis of the correlation between RSR and corresponding regional T_{sk} was performed to avoid the potentially confounding effects of between-participant factors on T_{sk} and RSR (particularly absolute work rate affecting SR). RSR and regional T_{sk} were not correlated in any participant at either exercise intensity or across measurement periods (mean ± SD Pearson's r correlation: I1 0.14 ± 0.34, I2 0.06 ± 0.17).

Paragraph 21 *Sex Comparison:* No significant differences in regional T_{sk} were present between sexes at any measurement period with exception to baseline. Similarly to the females, the lowest regional T_{sk} for males at baseline of 25.8°C was at the heels, compared to the highest of 32.5°C observed on the anterior upper arm. T_{sk} at baseline was significantly higher in females at all regions of the upper body (torso: posterior medial upper, posterior lateral upper, $p<0.05$; anterior upper, anterior medial lower, anterior lateral lower, posterior medial lower, posterior lateral lower, $p<0.01$; sides, $p<0.001$). The posterior medial upper, posterior lateral upper, anterior medial lower and posterior lateral lower regions did not show significance following Bonferroni correction. Absolute regional T_{sk} increased significantly at only the feet and ankles during I1, with most sites on the torso and the anterior arms increasing from I1 to I2. The mean increase in T_{sk} over all regions during pad application was 0.9°C during I1 and 0.8°C during I2, reflecting the impact of the procedure on T_{sk} (For complete regional T_{sk} data see Supplemental Digital Content 4 (SDC-4)). No correlation between RSR and regional T_{sk} was observed in males (Pearson's r correlation: I1 0.17 ± 0.23, I2 -0.11 ± 0.19).

Discussion

Paragraph 22 The present study aimed to produce a whole body sweat map of aerobically trained Caucasian females at two exercise intensities in a temperate environment. A secondary aim of the study was to compare this data with whole body sweat maps of aerobically trained Caucasian males tested under the same experimental conditions (38). The data have clearly illustrated significant intra and inter-regional variation in sweat rate in aerobically trained females, similar to that observed in males, and has shown large variation in absolute sweat rates between individuals. Regardless of the variation in absolute quantities of sweat produced, differences in distribution were observed between sexes, despite similarities in high and low sweat regions. Such differences should be considered in sex specific application of clothing design, clothing evaluation with thermal manikins and thermal modelling.

Paragraph 26 It is clear from the present data that absolute gross sweat rates were significantly higher in males compared to females exercising at the same relative work rate and unmatched for physical characteristics. This approach elicited a greater metabolic heat production in males (18) due to a higher absolute work rate compared to females and a greater body mass. This is largely reflected in the absolute regional sweat data in which 28 of the 34 regions measured were significantly higher in males than females at I1 and 32 of the 34 regions at I2. When considering distribution, at both exercise intensities the males had a significantly higher distribution of sweat towards the torso whilst the females had a significantly higher distribution towards the hands and feet in comparison to males. Comparing absolute sweat rates between sexes when exercising at similar rates of metabolic heat production (male I1 vs. female I2) still 17 of the 34 regions measured were significantly higher in males, mostly on the torso and legs, despite the similarity in GSL. Although the distribution of sweat was approximately similar between sexes, females did show a significantly higher distribution towards the arms (anterior and posterior) and hands (fingers, thumbs and dorsal hand) than the males, compared to a small number of regions showing a higher distribution of sweat on the torso in males compared to females. These data are consistent with previous upper body sweat mapping data produced by our laboratory using males and females of equal aerobic fitness (22). These data observed no overall effect of sex but a significant zone and sex interaction which showed that certain regions sweated more in males whilst other regions sweated more in females. Similarly to the present data, the highest normalised sweat rates were observed on the mid-central back in both sexes (with exception only to the area between the breasts in females), sweating to be greater on the posterior compared to anterior torso, and lowest on the extremities.

Paragraph 27 Explaining the observed differences in sweat distribution both within and between sexes requires further investigation. They cannot be explained by T_{sk} in the present data, and high versus low heat activated sweat gland distributions are reported to be similar in both males and females (28). Despite a higher heat activated sweat gland density in females there are no differences in total numbers of glands between sexes due to a greater surface area in males. Notably, a lower output per gland in females for a given thermal or pharmacological stimulus (5, 25, 33) may help explain the lower absolute RSRs in females compared to males, although not the regional differences, nor the impact on the heat balance this may have. In both sexes, regional sweat gland densities vary considerably over the body, with the greatest densities (glands.cm^{-2}) reported on the soles (620 ± 120), forehead (360 ± 60), and cheeks (320 ± 60), compared to the lowest values on the back, buttocks, arms and legs (ranging from 160 ± 30 to 120 ± 10, respectively) (41). Notably, this data used a small cadaver sample in which the type of sweat gland and its status as active or inactive was not discernible. A comprehensive review of torso sweat gland densities (inactive and active) is available from Machado-Moreira et al. (31), providing more reliable values. Regional glandular densities on the torso were relatively uniform (range:115-81 glands.cm^{-2} on the abdomen and the chest and abdomen (umbilicus), respectively), failing to explain the regional sweating variation observed in the present study. Alternative explanations include the number of active sweat glands, output per gland, and sudomotor sensitivity. Segmental sudomotor sensitivity calculated by Machado-Moreira et al. (31) closely matched regional sweat rate variation observed in the current data, supporting this factor as a likely explanation.

Applications: Applications for the current data can be found in a number of areas. Firstly, in models of human thermophysiology; these have moved over the last 5 decades from relatively simple 2-node models (a core and a skin compartment) (16) to highly detailed multi-node models that represent the whole body shape and calculate heat exchanges separately for many individual compartments (e.g. 63 body surface segments for Fiala (11)). This means that heat transfer is calculated differently for a chest section than for an arm section, for example. Until the current data were available, this difference was only in the heat transfer coefficients (difference in movements), but now also different sweat production levels for different areas can be included (11) providing an additional level of realism. The second application area is in clothing design. The body mapping data provided from the present and earlier work(12, 38), have been used by sportswear designers to target areas of high sweat generation with additional ventilation openings and with fabrics with different absorption and wicking properties, thereby improving heat loss (39). Thirdly, the obtained data feed directly into the design of sweating thermal manikins, used for the evaluation of clothing and environments; Being able to provide a more realistic sweat distribution adds an extra level or realism.

Paragraph 28 Conclusion: During exercise in a temperate environment aerobically trained Caucasian females demonstrated large regional variation in absolute regional sweat rates over the body but a consistent pattern of distribution. When compared to aerobically trained Caucasian males working at the same relative work rates, males showed a greater gross sweat loss compared to females owing to a greater metabolic heat production. Despite this, males and females showed similar 'high' and 'low' sweat distributions, however, slightly different overall patterns of distribution were present between sexes. Males had a relatively higher distribution of sweat towards the torso compared to females, where the arms, hands and feet contributed relatively more to total sweat loss in the females. Regional variation in sweat rate cannot be explained by regional skin temperature in the present study and does not correspond with regional sweat gland densities reported in the literature.

Limitations and Future Research: The present research has provided novel regional sweating data in Caucasian females and a comparison with Caucasian males under the same experimental conditions. It is difficult to dissociate the contributions of physical characteristics to the core temperature responses, requiring further studies using groups matched for physical characteristics to elucidate sex differences. Due to the applied and largely descriptive approach of this work it is beyond the scope of the paper to explain both the regional sweating variation and sex differences from a mechanistic viewpoint. Future work is needed to investigate regional differences in active eccrine sweat gland densities, gland sensitivity, and sudomotor innervation.

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Conflicts of Interest

Paragraph 30 The research presented was co-funded by the Adidas Innovation Team, Germany, and the Environmental Ergonomics Research Centre, Loughborough University. The authors were fully responsible for the conduct of the trial and the data.

The authors declare that there are no conflicts of interest.

The results from the present study do not constitute endorsement by the American College of Sports Medicine.

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Table Captions

Table 1. Descriptive statistics for all regions sampled at I1 and I2 for female subjects. Statistical comparison of sweat rates within each region between exercise intensities for both absolute and normalised data, corrected and uncorrected for multiple comparisons.

n=number of participants. Grey shading in columns for normalised ratio data indicates significant deviation from 1, i.e. average sweat rate. A decrease in median sweat rate ratio between intensities is indicated by black shading in the intensity comparison column. Sudomotor sensitivity for all regions tested, calculated as changes in regional sweat rate divided by change in Tcore (ΔTcore), for both intensities and overall (Taylor et al. 2006). For conversion of absolute sweat rates (in $g.m^{-2}.h^{-1}$) to other units: divide by 600 to get $mg.cm^{-2}.min^{-1}$, or by 10,000 to get $mg.cm^{-2}.h^{-1}$. Level of significance with no correction for multiple comparisons: *p<0.05, **p<0.01, ***p<0.001. Level of significance following Bonferroni correction: # p<0.05, ## p<0.05, ### p<0.0001, $ 0.05<p<0.1.

Table 2. Comparison of male and female absolute ($g.m^{-2}.h^{-1}$) and ratio regional sweat data for exercise intensity 1 (I1) and 2 (I2). A comparison of male exercise intensity 1 and female intensity 2 absolute and ratio regional sweat data are presented in the far right hand columns. Level of significance for male vs. female comparisons with no correction for multiple comparisons: *p<0.05, **p<0.01, ***p<0.001. Level of significance following Bonferroni correction: # p<0.05, ## p<0.05, ### p<0.0001, $ 0.05<p<0.1.

Figure Captions

Figure 1. Absolute mean GSL ($g.h^{-1}$) and absolute mean metabolic rate (W) for trained females and males at exercise intensity 1 (I1) and intensity 2 (I2). Male data has been modified from Smith and Havenith 2011 .

Figure 2. Absolute regional median sweat rates of female athletes at exercise intensity 1 (Panel A), and exercise intensity 2 (Panel B). *Note: The sweat rate scale is the same as that used for male absolute sweat maps from Smith and Havenith 2011 to allow direct comparison between data sets.*

Figure 3. Normalised regional median sweat rates of female athletes at exercise intensity 1 (Panel A), and exercise intensity 2 (Panel B).

Figure 4. Absolute (Panel A) and normalised (Panel B) regional median sweat rates of male athletes at exercise intensity 1 and 2. These data have been adapted from Smith and Havenith for direct comparison with the female data.

List of Supplemental Digital Content

Supplemental Digital Content 1.doc: Text describing anthropometric measurements and absorbent pad calculations.

Supplemental Digital Content 2.pptx: Figure illustrating sweat mapping absorbent pad placement.

Supplemental Digital Content 3.pptx: Tables 1-4 showing the significance level of comparison of absolute sweat rates for all regions at exercise intensity 1 and 2, with and without Bonferroni correction.

Supplemental Digital Content 4.pptx: Tables 1-2 showing regional skin temperature in female (Table 1) and male (Table 2) participants during baseline and pre/post pad application at exercise intensity 1 and 2. Data show the significance level of comparison of regional skin temperature between measurement periods, with and without Bonferroni correction.

Table 1

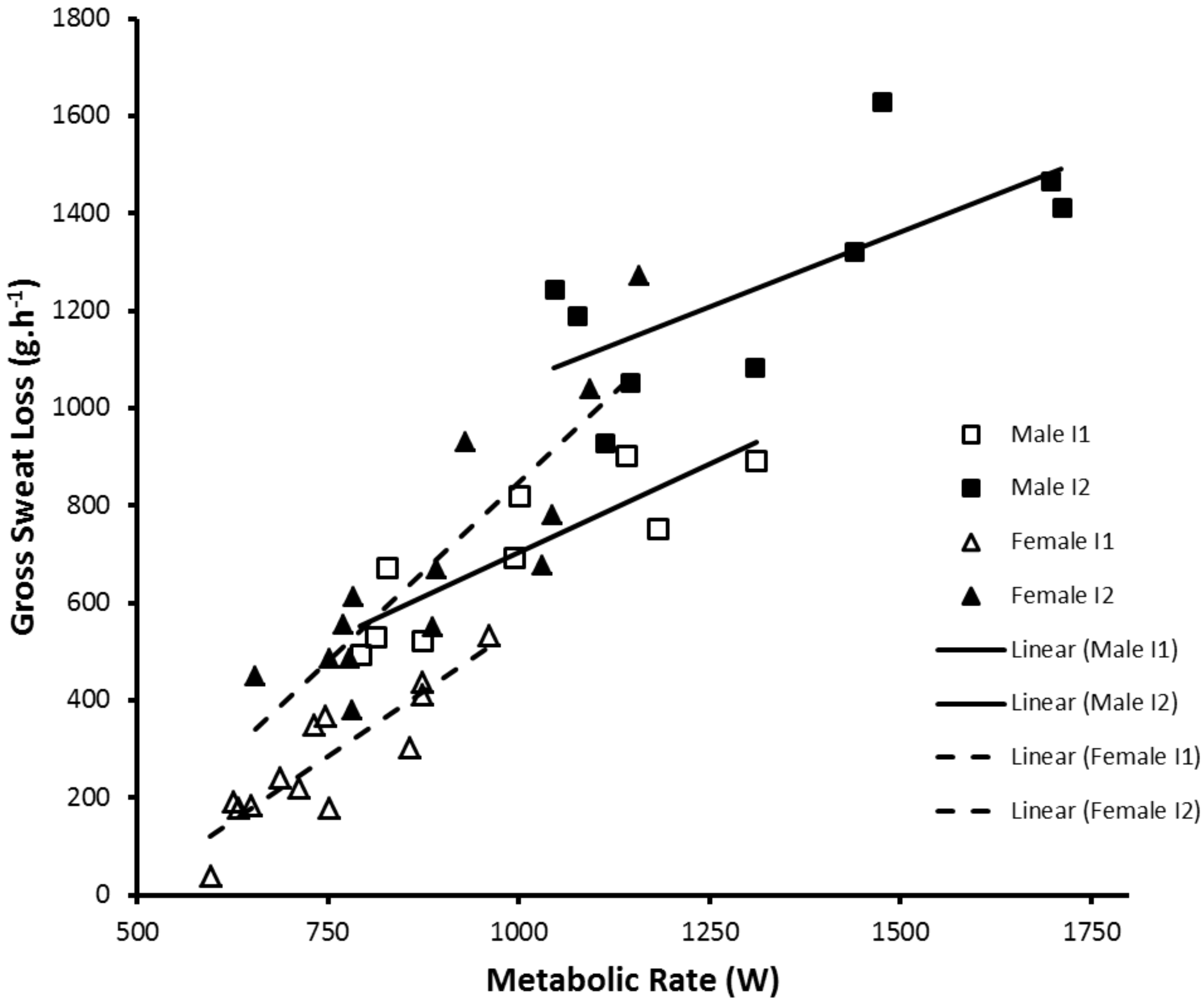
Table 1.

		Surface area	Absolute sweat data (g.m^{-2}.h^{-1})										Normalised ratio data				Pearson's r		Significance level of intensity comparison		Sudomotor sensitivity		
			I1					I2					I1		I2		GSL and RSR				(g.m^{-2}.h^{-2}.°C^{-1})		(mg.cm^{-2}.min^{-1}.°C^{-1})
	n	m^2	min	max	median	mean	SD	min	max	median	mean	SD	Median	IQR	Median	IQR	I1	I2	Absolute data	Normalised ratio data	I1	I2	Overall
shoulders	13	0.052	3	240	40	80	83	65	570	138	189	130	0.72	0.78	0.94	0.39	0.92	0.72	***##	***#	78	426	0.42
upper chest	13	0.023	0	300	58	64	80	44	478	199	185	131	0.38	0.64	0.88	0.51	0.52	0.66	***#	***#	112	613	0.41
med upper bra	13	0.009	0	93	22	34	39	0	402	145	153	142	0.27	0.46	0.70	1.23	0.60	0.60	**	*	43	535	0.34
lat upper bra	13	0.010	0	86	0	18	29	0	180	46	72	72	0.00	0.18	0.34	0.44	0.79	0.81	**$	**$	0	202	0.16
med lower bra	13	0.009	0	184	0	27	52	0	361	57	92	112	0.00	0.35	0.27	0.52	0.53	0.61	*	-	0	248	0.21
lat lower bra	13	0.010	0	48	0	5	13	0	76	0	16	26	0.00	0.00	0.00	0.09	0.65	0.67	-	-	0	0	0.03
bra triangle	13	0.002	0	2251	139	418	664	0	3940	723	912	1038	1.19	6.85	4.85	7.01	0.39	0.51	**$	-	270	2539	2.04
lat mid chest	13	0.032	0	210	31	55	63	16	221	83	109	68	0.36	0.50	0.51	0.39	0.79	0.64	***#	-	60	225	0.24
med mid chest	13	0.016	0	159	57	67	57	31	253	97	130	75	0.62	0.53	0.70	0.37	0.72	0.50	***##	-	110	174	0.29
sides	13	0.034	23	322	67	96	88	81	350	211	192	86	0.71	0.57	0.93	0.62	0.71	0.45	***#	-	130	626	0.43
ant lower	13	0.016	0	292	49	73	83	12	384	106	144	105	0.52	0.48	0.70	0.78	0.59	0.31	***#	-	95	248	0.32
lat upper back	13	0.035	7	399	138	162	130	119	601	324	338	151	1.44	0.64	1.86	0.40	0.89	0.76	***###	-	268	807	0.76
med upper back	13	0.019	21	814	223	282	227	141	963	470	496	228	2.29	1.37	2.86	1.16	0.80	0.69	***##	-	433	1076	1.11
lat mid upper back	13	0.017	0	284	13	80	105	0	413	137	186	137	0.18	1.09	0.92	0.42	0.68	0.77	**	-	25	538	0.42
lat mid lower back	13	0.017	0	273	16	66	88	30	337	83	129	114	0.33	0.67	0.66	0.60	0.83	0.67	**$	-	31	292	0.29
med mid back	13	0.017	0	473	133	166	146	45	613	304	340	162	1.53	1.06	1.94	0.48	0.88	0.85	***###	*	258	743	0.76
pos lower back	13	0.015	0	466	132	164	168	14	598	333	300	190	1.36	2.26	1.83	1.13	0.79	0.55	**$	-	257	875	0.67
ant upper leg	12	0.065	32	275	111	123	71	44	451	160	190	117	1.20	0.47	0.97	0.40	0.89	0.84	**$	-	215	214	0.42
med upper leg	12	0.065	28	276	71	101	73	47	351	138	152	89	1.00	0.18	0.82	0.15	0.82	0.87	**$	-	137	293	0.34
pos upper leg	12	0.065	41	221	88	100	54	67	293	114	144	84	0.97	0.34	0.75	0.32	0.77	0.72	**	-	171	112	0.32
lat upper leg	12	0.065	57	205	111	118	49	53	366	123	166	106	1.28	0.35	0.91	0.40	0.72	0.70	*	*	216	51	0.37
ant lat lower leg	13	0.049	19	364	75	122	98	24	372	140	164	109	1.12	0.74	0.90	0.65	0.78	0.73	**	-	145	285	0.37
ant med lower leg	13	0.049	31	308	99	132	85	30	448	159	197	127	1.39	0.31	1.23	0.40	0.78	0.73	**$	-	193	260	0.44
pos lower leg	13	0.095	42	218	81	102	57	57	295	112	141	77	0.99	0.45	0.74	0.30	0.77	0.72	**$	*	158	134	0.32
ant upper arm	13	0.060	0	172	67	80	61	58	282	133	145	72	0.76	0.24	0.83	0.17	0.93	0.91	***##	-	131	287	0.33
pos upper arm	13	0.060	0	177	52	68	67	19	272	138	139	74	0.55	0.57	0.78	0.29	0.89	0.78	***##	*	101	374	0.31
ant lower arm	13	0.053	0	293	68	101	96	51	427	185	188	106	0.86	0.86	1.09	0.20	0.87	0.87	***##	*	131	511	0.42
pos lower arm	13	0.052	0	275	89	104	98	12	393	257	209	123	0.97	0.98	1.22	0.43	0.91	0.71	**$	-	173	729	0.47
thumbs	13	0.010	16	233	104	118	80	56	503	142	195	119	1.16	1.01	1.08	0.40	0.59	0.39	*	-	203	161	0.44
fingers	13	0.039	13	135	70	70	40	23	148	113	103	37	0.68	0.61	0.69	0.34	0.47	0.27	**$	-	136	185	0.23
palms	13	0.030	1	152	43	58	44	15	153	82	80	32	0.62	0.32	0.55	0.18	0.56	0.31	*	-	83	168	0.18
back hand	13	0.033	9	315	106	118	96	34	308	151	163	90	1.02	1.03	1.07	0.45	0.53	0.64	*	-	205	199	0.37
buttocks	13	0.037	15	267	120	110	68	62	325	192	190	74	1.07	0.71	1.17	0.33	0.56	0.23	**$	-	233	314	0.43
sole	13	0.017	59	160	116	119	33	56	154	125	119	33	1.40	1.66	0.89	0.58	0.09	-0.20	-	**$	225	40	0.27
dorsal foot	13	0.056	32	157	139	115	46	34	195	131	124	49	1.32	0.77	0.81	0.57	0.28	0.13	-	**$	269	-31	0.28
toes	13	0.010	81	219	114	130	41	29	213	108	121	52	1.66	1.84	0.91	0.88	-0.33	-0.52	-	**$	222	-28	0.27
heel	13	0.007	69	233	161	148	52	46	209	131	129	45	1.43	1.95	0.92	0.67	-0.34	-0.33	-	**$	313	-132	0.29
med ankle	13	0.015	16	368	101	144	130	21	332	192	196	95	1.10	1.18	1.17	0.92	0.71	0.02	-	-	197	392	0.44
lat ankle	13	0.014	0	284	47	91	92	0	260	128	127	68	0.73	0.64	0.85	0.63	0.65	-0.04	-	-	91	353	0.28

Table 2

					Male I1 and Female I2 Sweat data comparison	
	Absolute sweat data ($g.m^{-2}.h^{-1}$)		Normalised ratio data		Absolute data ($g.m^{-2}.h^{-1}$)	Ratio data
	I1	I2	I1	I2		
shoulders	*** ###	*** ##	**	**	*	-
upper chest	*** ###	*** ###	** $	*	*	-
lat mid chest	*** ###	*** ##	** $	*	*** ##	-
med mid chest	*** ###	*** ##	** $	**	*** ##	*
sides	**	**	-	-	-	-
ant lower	**	*** ##	-	-	-	-
lat upper back	*** ###	*** ###	*	-	**	-
med upper back	*** #	*** ##	-	-	*	-
lat mid upper back	*** ###	*** ###	**	*	**	-
lat mid lower back	*** ###	*** ##	*** ##	*** ##	** $	** $
med mid back	*** ###	*** ##	** $	*	*** ##	*
pos lower back	*** ##	*** #	*	-	**	-
ant upper leg	** $	** $	-	-	-	-
med upper leg	*	*	-	-	-	-
pos upper leg	*** #	**	-	-	-	-
lat upper leg	**	** $	-	-	*	*
ant lat lower leg	*	**	-	-	*	-
ant med lower leg	**	*** #	-	-	*	-
pos lower leg	*** ##	*** ##	-	-	**	-
ant upper arm	*	**	-	**	-	*** ##
pos upper arm	-	**	-	-	-	*
ant lower arm	*	** $	-	-	-	*
pos lower arm	*	**	-	-	-	-
thumbs	-	-	*	**$	-	**
fingers	-	*	*	**	-	*
palms	-	*	*	*	-	-
back hand	-	-	-	*	-	**
buttocks	**	** $	-	-	-	-
sole	*	**	**	-	**	-
top foot	*	**	-	-	**	-
toes	-	*	**	*	-	-
heel	-	*	** $	*	-	-
med ankle	*	**	-	-	*	-
lat ankle	*	**	-	-	-	-

Figure 1



1800
1600
1400
1200
1000
800
600
400
200
0
Gross Sweat Loss (g.h-1)
500
750
1000
1250
1500
1750
Metabolic Rate (W)
Male I1
Male I2
Female I1
Female I2
Linear (Male I1)
Linear (Male I2)
Linear (Female I1)
Linear (Female I2)

Figure 2

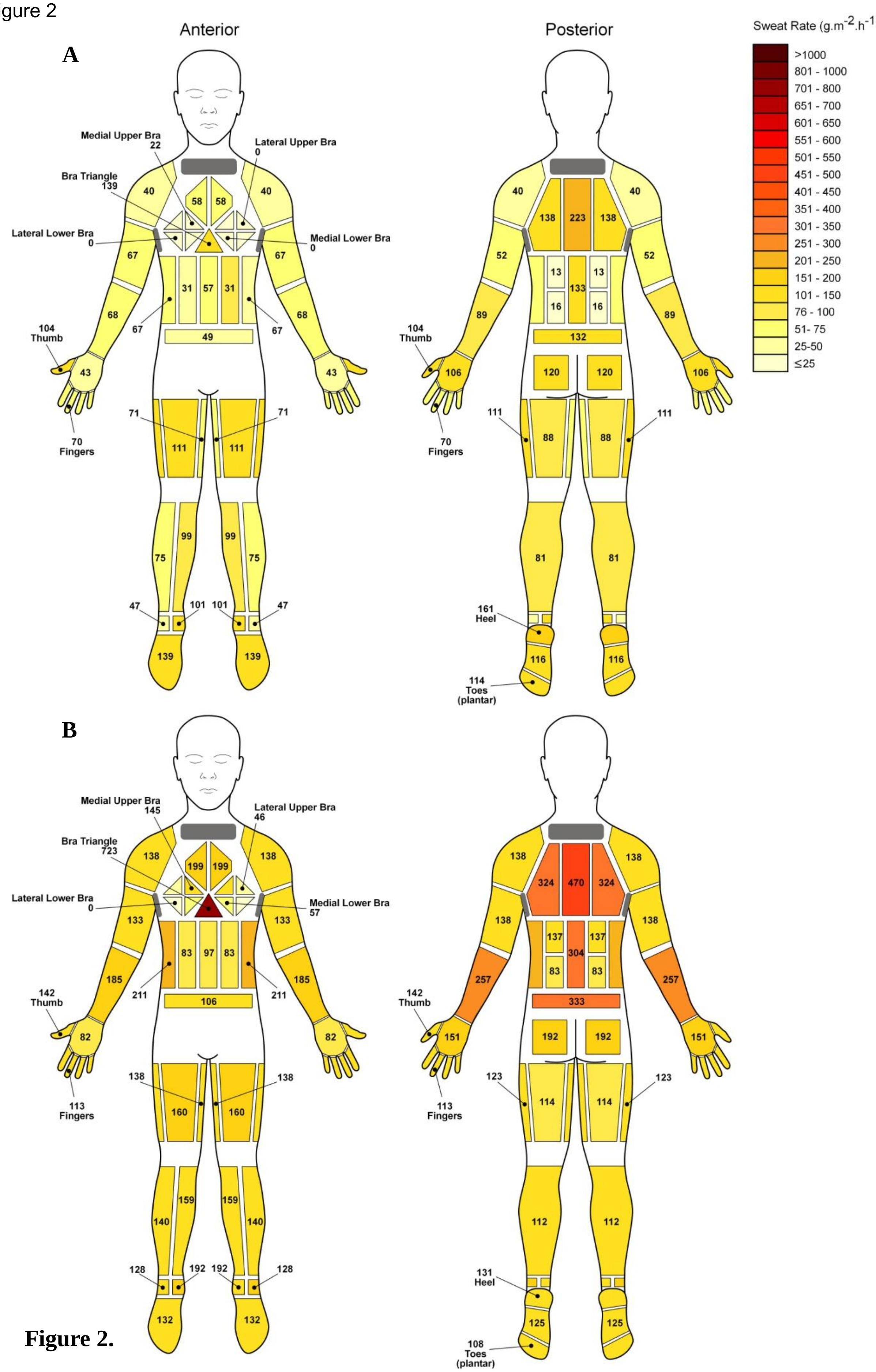


Figure 2.

Figure 3

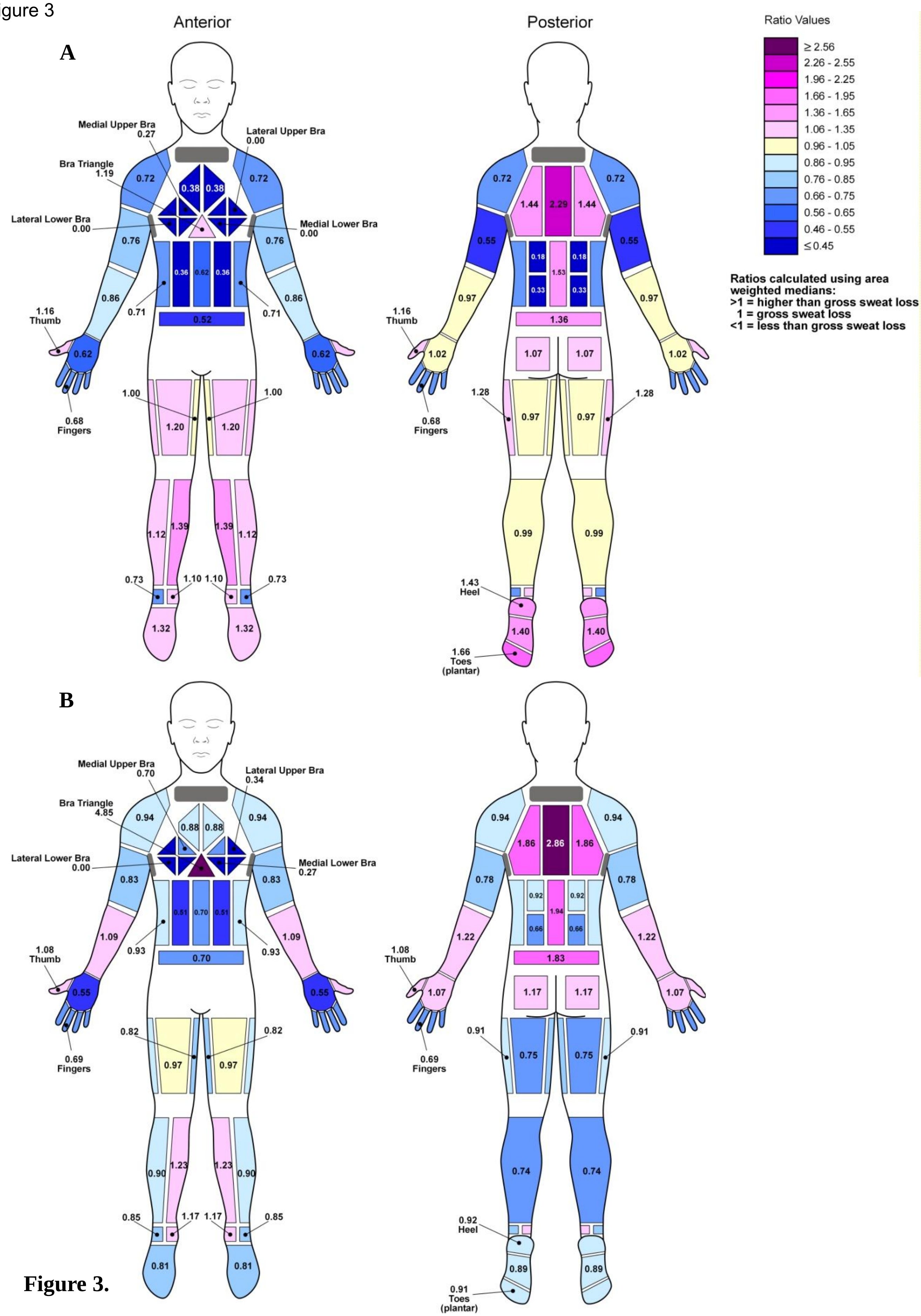


Figure 3.

Figure 4

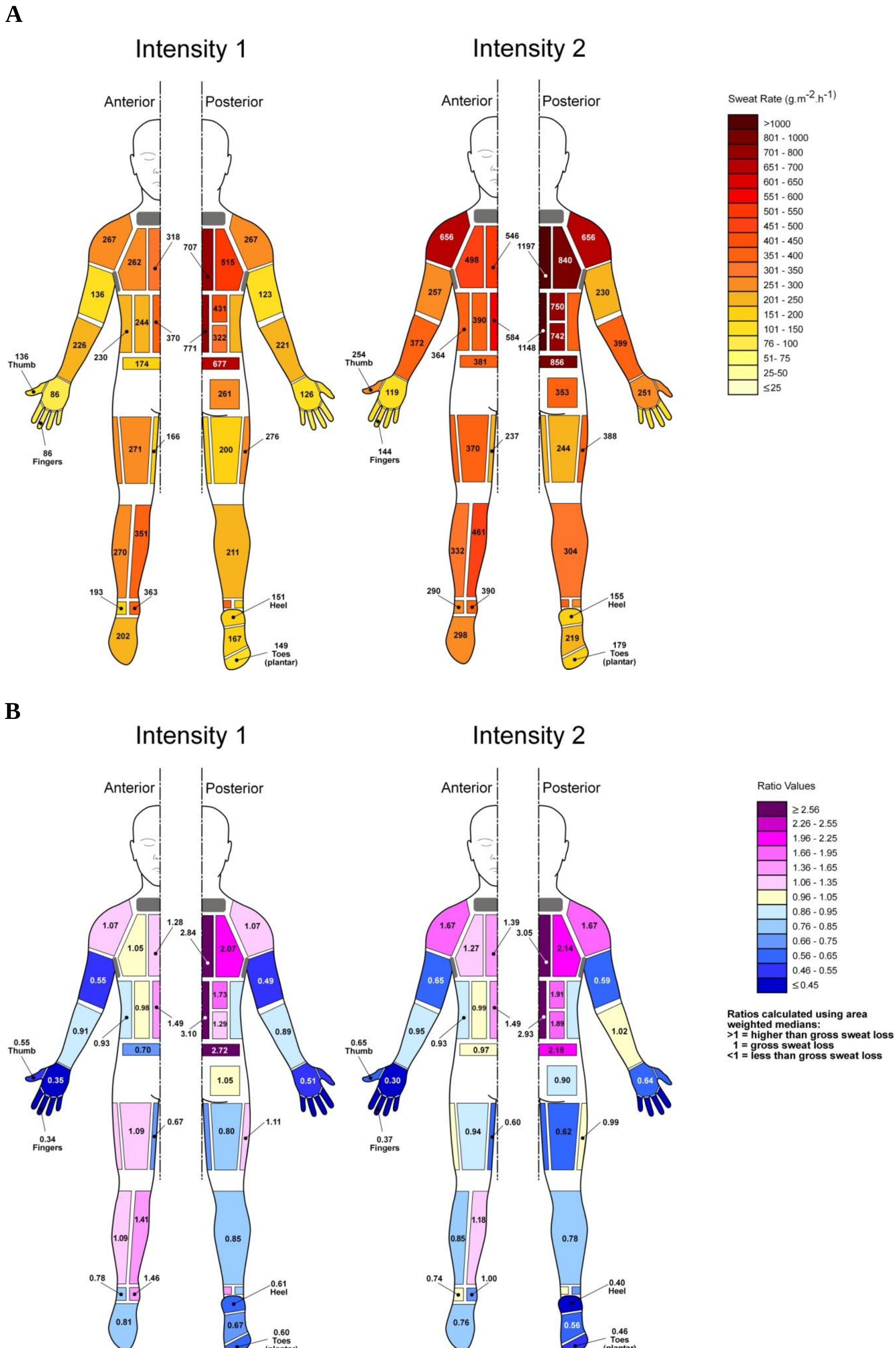


Figure 4.

Supplemental Digital Content 1

Sweat Mapping: Anthropometric Measurements and Pad Calculations

UPPER BODY/TORSO

Anatomical Measurement Descriptions

location	measurement description
biacromial diameter	distance between the right and left acromion processes
upper body length	distance between the right acromion process and the height of the right anterior iliac spine
upper arm circum.	the circumference at the mid point of the upper arm (mid point of the distance from the superolateral surface of the acromion process to the posterior surface of the olecranon process of the ulna)
upper circum.	circum. at the level of the upper body length * 0.62
mid-upper circum.	circum. at the level of the upper circumference height / 2
mid-lower circum.	circum. at the level of the mid-upper circum. height / 2
lower circum.	circum at the level of the right and left anterior superior iliac spine

Anterior and Posterior Torso Width Calculations for Absorbent Pads

Anterior upper width = upper circumference*0.32
Anterior mid width = mid-upper circumference*0.37
Anterior lower width = lower circumference*0.4
Posterior upper width = upper circumference*0.4
Posterior mid-upper width = mid-upper circumference*0.43
Posterior mid-lower width = mid-lower circumference*0.37
Posterior lower width = lower circumference*0.38

Absorbent Pad Calculations

Note: Bra pads were pre-sized to fit based on bra cup size. These pad calculations are not included.

Right and left shoulder
Width: biacromial diameter*0.32
Medial side: upper arm circumference*0.54
Lateral side: arm circumference*0.81
Anterior/posterior side: biacromial diameter*0.12

Right and left anterior upper
Lateral height: upper body length * 0.18
Medial height: upper body length * 0.22
Width: upper circumference * 0.14

Right, left, and centre anterior mid
Height: upper body length * 0.34
Upper width: anterior mid with/3
Lower width: anterior lower width/3

Right and left side
Height: upper body length * 0.55
Upper width: upper circumference * 0.07
Lower width: lower circumference * 0.09

Anterior lower
Height: upper body length * 0.10
Width: equal to anterior lower width
Right and left posterior upper
Medial height: upper body length*0.38
Lateral height: upper body length*0.31
Upper width: no ‘upper side’ but width is same as centre pos upper
Lower width: posterior mid-upper width/3

Centre posterior upper
Height: upper body length*0.38
Upper width: posterior upper width/3
Lower width: posterior mid-upper width/3

Right and left posterior mid-upper
Height: center posterior mid pad height/2
Upper width: posterior mid-upper width/3
Lower width: posterior mid-lower width/3

Right and left posterior mid lower
Height: centre posterior mid pad height/2
Upper width: posterior mid-lower width/3
Lower width: posterior lower width/3

Centre posterior mid
Height: upper body length*0.34
Upper width: posterior mid-upper width/3
Lower width: posterior lower width/3

Posterior lower
Height: upper body length*0.10
Width: equal to posterior lower width

LEGS

Anatomical Measurement Descriptions

Location	Pad Measurement Description
anterior upper leg length	distance from the anterior superior iliac spine to the proximal edge of the patella
anterior lower leg length	distance from the distal edge of the patella to the level of the proximal surface of the medial and lateral malleoli
upper leg: upper circum.	circumference of the upper leg at the height of the top of the absorbent pad (upper leg length*0.6)
upper leg: mid circum.	circumference of the upper leg at the midpoint of the absorbent pad (upper leg length*0.6/2)
upper leg: lower circum.	circumference of the upper leg directly at the height of the proximal edge of the patella (level of the bottom of the absorbent pad)
lower leg: upper circum.	circumference of the lower leg at the height of the distal edge of the
lower leg: mid circum.	circumference at the midpoint of the lower leg (lower leg length/2)
lower leg: lower circum.	circumference of the lower leg at the level of the proximal surface of the medial and lateral malleoli
lower leg: anterior/posterior division	medial malleolus to medial condyle of femur. lateral malleolus to lateral condyles of femur
anterior lower leg: upper width	width across anterior division of the leg at the height of the distal edge of the patella
posterior lower leg: upper width	width across posterior division of the leg at the height of the distal edge of the patella.
anterior lower leg: mid width	width across anterior division of the leg at the midpoint of the lower leg (lower leg length/2)
posterior lower leg: mid width	width across posterior division of the leg at the midpoint of the lower leg (lower leg length/2)
anterior lower leg: lower width	width across the anterior division of the leg at the level of the proximal sufrace of the medial and lateral malleoli
posterior lower leg: lower width	width across the posterior division of the leg at the level of the proximal surface of the medial and lateral malleoli
hip circum: ant. sup. Iliac spine	circumference of the waist at the level of the anterior superior iliac
hip circum: head of femur	circumference of the waist at the level of the head of femur

Absorbent Pad Calculations

Right and left upper leg pads: anterior/posterior/medial/lateral
Height: right/left leg length*0.6
Upper width: right/left upper circumference/4
Mid width: right/left mid circumference/4
Lower width: right/left lower width/4

Right and left anterior lower leg pads: medial/lateral
Height: equal to right/left lower leg length
Upper width: right/left lower leg anterior upper width/2
Mid width: right/left lower leg anterior mid width/2
Lower width: right/left lower leg anterior width/2

Right and left posterior lower leg
Height: equal to right/left lower leg length
Upper width: right/left lower leg posterior upper width
Mid width: right/left lower leg posterior mid width
Lower width: right/left lower leg posterior lower width

ARMS, HANDS, BUTTOCKS AND FEET

Anatomical Measurement Descriptions

Location	Pad Measurement Description
upper arm length	distance from the superolateral surface of the acromion process to the posterior surface of the olecranon process of the ulna * 0.7
lower arm length	distance from the posterior surface of the olecranon process of the ulna to the styloid process of the ulna
upper arm upper circum	circumference of the upper arm at the height of the top of the absorbent pad (upper arm length * 0.7)
upper arm mid circum	circumference at the midpoint of the upper arm pad length (upper arm length * 0.7/2)
upper arm lower circum	circumference of the upper arm at the height of the superior surface of the olecranon process of the ulna
lower arm upper circum	circumference of the lower arm at the height of the olecranon process of the ulna
upper arm mid circum	circumference at the midpoint of the lower arm (lower arm length/2)
lower arm lower circum	circumference of the lower arm at the height of the superior surface the styloid process of the ulna
(Anterior and Posterior pad widths are produced by dividing the circumferences at the 3 points by 2)	

Absorbent Pad Calculations

Right and left upper arm pads: anterior and posterior
Height: right/left upper arm height*0.7
Upper width: right/left upper arm upper circumference/2
Mid width: right/left upper arm mid circumference/2
Lower width: right/left upper arm lower circumference/2

Right and left lower arm pads: anterior and posterior
Height: equal to right/left lower arm length
Upper width: right/left lower arm upper circumference/2
Mid width: right/left lower arm mid circumference/2
Lower width: right left lower arm lower circumference/2

Right and left medial ankle
Height: right/left medial ankle height*0.6
Width: right/left ankle circumference/2

Right and left lateral ankle
Height: right/left lateral ankle height*0.6
Width: right/left ankle circumference/2

Right and Left buttocks
Height: upper body length*0.26
Width: circumference at anterior superior iliac spine*0.18

Supplemental Digital Content 2

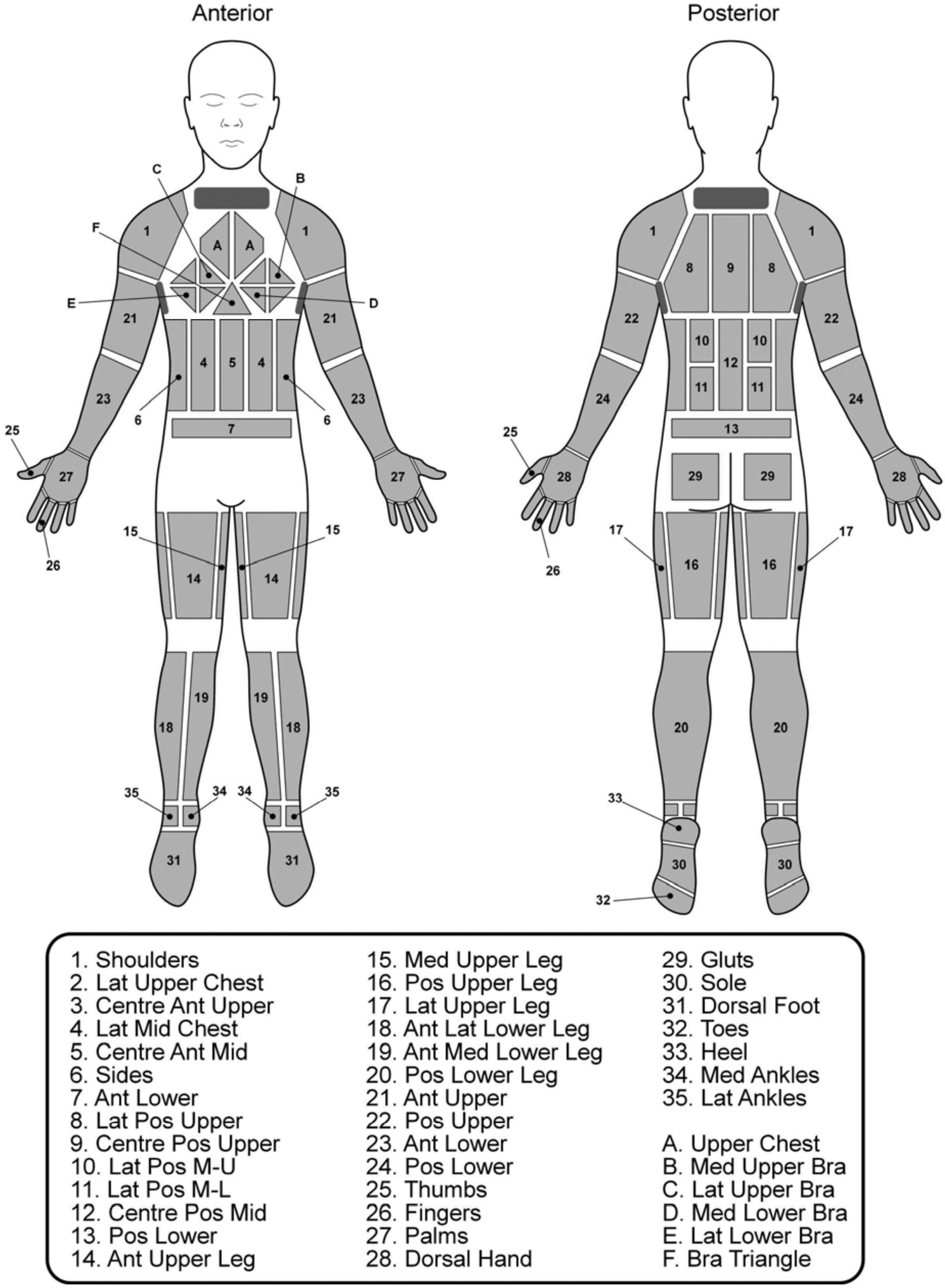


Figure 1. Absorbent pad locations and labels for female sweat mapping. *Note: Pads 2 and 3 are specific to male sweat maps due to differences in upper chest pads between sexes (See Smith and Havenith, 2011). Numbering has been kept constant between male and female sweat maps to allow easy comparison.*

Supplemental Digital Content 3

Table 1. Significance level of comparison of absolute sweat rates for all regions measured at exercise intensity 1, uncorrected for multiple comparisons.

	shoulders	upper chest	med. upper bra	lat. upper bra	med. lower bra	lat. lower bra	bra triangle	lat. mid chest	med. mid chest	sides	ant. lower	lat. upper back	med. upper back	lat. mid upper back	lat. mid lower back	med. mid back	pos. lower back	ant. upper leg	med. upper leg	pos. upper leg	lat. upper leg	ant. lat lower leg	ant. med lower leg	pos. lower leg	ant. upper arm	pos. upper arm	ant. lower arm	pos. lower arm	thumbs	fingers	palms	back hand	buttocks	sole	top foot	toes	heel	med. ankle
upper chest	-																																					
med. upper bra	≤0.05	-																																				
lat. upper bra	≤0.01	≤0.05	-																																			
med. lower bra	≤0.01	-	-	-																																		
lat. lower bra	≤0.01	≤0.05	≤0.01	-	-																																	
bra triangle	-	-	-	≤0.05	≤0.05	≤0.05																																
lat. mid chest	-	-	-	≤0.01	-	≤0.01	-																															
med. mid chest	-	-	≤0.05	≤0.001	≤0.05	≤0.01	-	-																														
sides	-	-	≤0.05	≤0.01	≤0.05	≤0.01	-	≤0.01	-																													
ant. lower	-	-	-	≤0.05	≤0.05	≤0.01	-	-	-	-																												
lat. upper back	≤0.001	≤0.01	≤0.01	≤0.001	≤0.01	≤0.001	-	≤0.001	≤0.01	≤0.01	≤0.01																											
med. upper back	≤0.01	≤0.01	≤0.01	≤0.001	≤0.01	≤0.01	-	≤0.001	≤0.01	≤0.001	≤0.01	≤0.01																										
lat. mid upper back	-	-	-	≤0.05	-	≤0.05	-	-	-	-	-	≤0.01	≤0.001																									
lat. mid lower back	-	-	-	≤0.05	-	≤0.05	-	-	-	-	-	≤0.001	≤0.001	-																								
med. mid back	≤0.01	≤0.01	≤0.01	≤0.01	≤0.01	≤0.01	-	≤0.01	≤0.01	≤0.01	≤0.05	-	≤0.01	≤0.01	≤0.001																							
pos. lower back	≤0.05	≤0.05	≤0.01	≤0.01	≤0.01	≤0.01	-	≤0.05	≤0.05	-	≤0.05	-	≤0.05	≤0.01	≤0.01	-																						
ant. upper leg	≤0.05	-	≤0.001	≤0.001	≤0.001	≤0.001	-	≤0.01	≤0.05	-	-	-	≤0.01	-	≤0.01	≤0.05	-																					
med. upper leg	-	-	≤0.01	≤0.001	≤0.001	≤0.001	-	≤0.05	-	-	-	≤0.05	≤0.01	-	≤0.05	≤0.01	≤0.05	≤0.05																				
pos. upper leg	-	-	≤0.001	≤0.001	≤0.001	≤0.001	-	≤0.05	-	-	-	≤0.05	≤0.01	-	-	≤0.05	-	≤0.05	-																			
lat. upper leg	-	-	≤0.001	≤0.001	≤0.001	≤0.001	-	≤0.01	≤0.01	-	-	-	≤0.01	-	≤0.05	-	-	-	-	≤0.05																		
ant. lat lower leg	≤0.05	-	≤0.01	≤0.01	≤0.01	≤0.001	-	≤0.05	-	-	≤0.05	-	≤0.05	-	≤0.01	-	-	-	-	-	-																	
ant. med lower leg	≤0.01	-	≤0.001	≤0.001	≤0.001	≤0.001	-	≤0.01	≤0.05	-	≤0.05	-	≤0.05	-	≤0.001	-	-	-	≤0.01	≤0.05	-	-																
pos. lower leg	-	-	≤0.001	≤0.001	≤0.001	≤0.001	-	≤0.05	-	-	-	≤0.05	≤0.01	-	-	≤0.05	-	-	-	-	-	-	≤0.01															
ant. upper arm	-	-	≤0.05	≤0.001	≤0.01	≤0.001	-	-	-	-	-	≤0.01	≤0.01	-	-	≤0.05	≤0.05	≤0.05	-	-	≤0.05	-	≤0.05	-														
pos. upper arm	-	-	-	≤0.01	≤0.05	≤0.01	-	-	-	-	-	≤0.01	≤0.01	-	-	≤0.01	≤0.05	≤0.05	-	-	≤0.05	≤0.05	≤0.01	-	-													
ant. lower arm	-	-	≤0.05	≤0.01	≤0.01	≤0.01	-	-	-	-	-	≤0.05	≤0.01	-	-	-	-	-	-	-	-	-	-	-	-	≤0.01												
pos. lower arm	-	-	≤0.05	≤0.01	≤0.01	≤0.01	-	≤0.05	-	-	-	≤0.05	≤0.01	-	-	-	-	-	-	-	-	-	-	-	-	≤0.01	-											
thumbs	-	-	≤0.01	≤0.01	≤0.01	≤0.001	-	≤0.05	-	-	-	-	≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	≤0.05	-	-										
fingers	-	-	-	≤0.01	≤0.05	≤0.001	-	-	-	-	-	≤0.05	≤0.01	-	-	≤0.05	-	≤0.05	-	-	≤0.05	≤0.05	≤0.05	-	-	-	-	-	≤0.01									
palms	-	-	-	≤0.05	-	≤0.01	-	-	-	-	-	≤0.01	≤0.01	-	-	≤0.05	≤0.05	≤0.01	-	≤0.05	≤0.01	≤0.05	≤0.01	≤0.05	-	-	≤0.05	≤0.05	≤0.01	-								
back hand	-	-	≤0.05	≤0.01	≤0.01	≤0.01	-	-	-	-	-	-	≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	≤0.05							
buttocks	-	-	≤0.01	≤0.01	≤0.001	≤0.001	-	-	-	-	-	-	≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	≤0.05	-	-	-	-	≤0.05	-						
sole	-	-	≤0.01	≤0.001	≤0.001	≤0.001	-	≤0.05	≤0.05	-	-	-	≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	≤0.05	-	-	-	≤0.001	≤0.001	-	-					
top foot	-	-	≤0.001	≤0.001	≤0.001	≤0.001	-	≤0.05	≤0.05	-	-	-	≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	≤0.01	≤0.01	-	-	-				
toes	-	-	≤0.01	≤0.001	≤0.01	≤0.001	-	≤0.05	≤0.05	-	-	-	≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	≤0.01	≤0.01	-	-	-	-			
heel	-	≤0.05	≤0.001	≤0.001	≤0.001	≤0.001	-	≤0.05	≤0.05	-	≤0.05	-	≤0.05	-	-	-	-	-	-	-	-	-	-	-	≤0.05	≤0.05	-	-	-	≤0.001	≤0.01	-	-	≤0.05	-	-		
med. ankle	≤0.05	-	≤0.01	≤0.01	≤0.01	≤0.01	-	≤0.05	≤0.05	-	-	-	≤0.05	-	≤0.05	-	-	-	-	-	-	-	-	-	≤0.05	≤0.01	≤0.05	-	-	≤0.05	≤0.05	-	-	-	-	-	-	
lat. ankle	-	-	-	≤0.05	≤0.05	≤0.01	-	-	-	-	-	≤0.05	≤0.01	-	-	≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	≤0.01

p ≤ 0.05	p ≤ 0.01	p ≤ 0.001

Supplemental Digital Content 3

Table 2. Significance level of comparison of absolute sweat rates for all regions measured at exercise intensity 1 after Bonferroni correction.

	shoulders	upper chest	med. upper bra	lat. upper bra	med. lower bra	lat. lower bra	bra triangle	lat. mid chest	med. mid chest	sides	ant. lower	lat. upper back	med. upper back	lat. mid upper back	lat. mid lower back	med. mid back	pos. lower back	ant. upper leg	med. upper leg	pos. upper leg	lat. upper leg	ant. lat lower leg	ant. med lower leg	pos. lower leg	ant. upper arm	pos. upper arm	ant. lower arm	pos. lower arm	thumbs	fingers	palms	back hand	buttocks	sole	top foot	toes	heel	med. ankle
upper chest	-																																					
med. upper bra	-	-																																				
lat. upper bra	-	-	-																																			
med. lower bra	-	-	-	-																																		
lat. lower bra	-	-	-	-	-																																	
bra triangle	-	-	-	-	-	-																																
lat. mid chest	-	-	-	-	-	-	-																															
med. mid chest	-	-	-	-	-	-	-	-																														
sides	-	-	-	-	-	-	-	-	-																													
ant. lower	-	-	-	-	-	-	-	-	-	-																												
lat. upper back	-	-	-	-	-	-	-	-	-	-	-																											
med. upper back	-	-	-	-	-	-	-	-	-	-	-	-																										
lat. mid upper back	-	-	-	-	-	-	-	-	-	-	-	-	-																									
lat. mid lower back	-	-	-	-	-	-	-	-	-	-	-	$	-	-																								
med. mid back	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$																							
pos. lower back	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																						
ant. upper leg	-	-	-	$	$	$p \le 0.05$	-	-	-	-	-	-	-	-	-	-	-																					
med. upper leg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																				
pos. upper leg	-	-	-	$p \le 0.05$	$p \le 0.01$	$p \le 0.05$	-	-	-	-	-	-	-	-	-	-	-	-	-																			
lat. upper leg	-	-	$p \le 0.05$	$p \le 0.01$	$p \le 0.01$	$p \le 0.01$	-	-	-	-	-	-	-	-	-	-	-	-	-	-																		
ant. lat lower leg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																	
ant. med lower leg	-	-	-	-	$p \le 0.05$	$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																
pos. lower leg	-	-	-	$	$p \le 0.05$	$p \le 0.05$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-															
ant. upper arm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-														
pos. upper arm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-													
ant. lower arm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-												
pos. lower arm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-											
thumbs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-										
fingers	-	-	-	-	-	$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-									
palms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-								
back hand	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
buttocks	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
sole	-	-	-	$p \le 0.05$	-	$p \le 0.001$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
top foot	-	-	-	$	-	$p \le 0.01$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
toes	-	-	-	$p \le 0.05$	-	$p \le 0.01$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
heel	-	-	-	$	-	$p \le 0.01$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
med. ankle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
lat. ankle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

$p \le 0.05$	(dark grey)	$p \le 0.01$	(light grey)	$p \le 0.001$	(black)	$0.1 < p \ge 0.05$	$

Supplemental Digital Content 3

Table 3. Significance level of comparison of absolute sweat rates for all regions measured at exercise intensity 2, uncorrected for multiple comparisons.

	shoulders	upper chest	med. upper bra	lat. upper bra	med. lower bra	lat. lower bra	bra triangle	lat. mid chest	med. mid chest	sides	ant. lower	lat. upper back	med. upper back	lat. mid upper back	lat. mid lower back	med. mid back	pos. lower back	ant. upper leg	med. upper leg	pos. upper leg	lat. upper leg	ant. lat lower leg	ant. med lower leg	pos. lower leg	ant. upper arm	pos. upper arm	ant. lower arm	pos. lower arm	thumbs	fingers	palms	back hand	buttocks	sole	top foot	toes	heel	med. ankle
upper chest	-																																					
med. upper bra	-	-																																				
lat. upper bra	p≤0.01	p≤0.01	p≤0.01																																			
med. lower bra	p≤0.01	p≤0.05	p≤0.05	-																																		
lat. lower bra	p≤0.01	p≤0.01	p≤0.01	p≤0.01	p≤0.05																																	
bra triangle	p≤0.05	p≤0.05	p≤0.05	p≤0.01	p≤0.01	p≤0.01																																
lat. mid chest	-	p≤0.05	-	p≤0.05	-	p≤0.001	p≤0.05																															
med. mid chest	-	-	-	p≤0.01	-	p≤0.001	p≤0.05	-																														
sides	-	-	-	p≤0.001	p≤0.05	p≤0.001	p≤0.05	p≤0.01	p≤0.05																													
ant. lower	-	-	-	-	-	p≤0.01	p≤0.05	-	-	-																												
lat. upper back	p≤0.001	p≤0.001	p≤0.01	p≤0.001	p≤0.001	p≤0.001	p≤0.05	p≤0.001	p≤0.001	p≤0.01	p≤0.01																											
med. upper back	p≤0.001	p≤0.001	p≤0.001	p≤0.001	p≤0.001	p≤0.001	-	p≤0.001	p≤0.001	p≤0.001	p≤0.001	p≤0.001																										
lat. mid upper back	-	-	-	p≤0.001	p≤0.05	p≤0.001	p≤0.05	p≤0.05	-	-	-	p≤0.001	p≤0.001																									
lat. mid lower back	-	-	-	p≤0.05	-	p≤0.01	p≤0.05	-	-	-	-	p≤0.001	p≤0.001	-																								
med. mid back	p≤0.01	p≤0.01	p≤0.01	p≤0.001	p≤0.001	p≤0.001	p≤0.05	p≤0.001	p≤0.001	p≤0.01	p≤0.01	-	p≤0.01	p≤0.001	p≤0.001																							
pos. lower back	p≤0.05	p≤0.05	p≤0.05	p≤0.001	p≤0.01	p≤0.001	p≤0.05	p≤0.01	p≤0.01	-	p≤0.05	-	p≤0.05	p≤0.05	p≤0.01	-																						
ant. upper leg	-	-	-	p≤0.001	p≤0.05	p≤0.001	p≤0.05	p≤0.05	-	-	-	p≤0.01	p≤0.001	-	p≤0.05	p≤0.001	p≤0.05																					
med. upper leg	-	-	-	p≤0.01	-	p≤0.001	p≤0.05	-	-	-	-	p≤0.001	p≤0.001	-	-	p≤0.001	p≤0.01	p≤0.01																				
pos. upper leg	-	-	-	p≤0.01	-	p≤0.001	p≤0.05	-	-	-	-	p≤0.001	p≤0.001	-	-	p≤0.001	p≤0.01	p≤0.05	-																			
lat. upper leg	-	-	-	p≤0.001	p≤0.05	p≤0.001	p≤0.05	-	-	-	-	p≤0.001	p≤0.001	-	-	p≤0.001	p≤0.01	-	-	p≤0.05																		
ant. lat lower leg	-	-	-	p≤0.01	-	p≤0.001	p≤0.05	-	-	-	-	p≤0.001	p≤0.001	-	-	p≤0.001	p≤0.01	p≤0.05	-	-	-																	
ant. med lower leg	-	-	-	p≤0.01	p≤0.05	p≤0.001	p≤0.05	p≤0.05	-	-	-	p≤0.01	p≤0.001	-	p≤0.05	p≤0.001	p≤0.05	-	p≤0.05	p≤0.01	-	p≤0.01																
pos. lower leg	-	-	-	p≤0.01	-	p≤0.001	p≤0.05	-	-	-	-	p≤0.001	p≤0.001	-	-	p≤0.001	p≤0.01	p≤0.01	-	-	-	-	p≤0.01															
ant. upper arm	-	-	-	p≤0.001	p≤0.05	p≤0.001	p≤0.05	-	-	-	-	p≤0.001	p≤0.001	-	-	p≤0.001	p≤0.01	-	-	-	-	-	-	-														
pos. upper arm	-	-	-	p≤0.001	-	p≤0.001	p≤0.05	-	-	-	-	p≤0.001	p≤0.001	-	-	p≤0.001	p≤0.01	-	-	-	-	-	-	-	-													
ant. lower arm	-	-	-	p≤0.001	p≤0.001	p≤0.001	p≤0.05	p≤0.05	-	-	-	p≤0.01	p≤0.001	-	-	p≤0.01	-	-	p≤0.05	p≤0.05	-	-	-	p≤0.05	p≤0.01	p≤0.01												
pos. lower arm	-	-	-	p≤0.001	p≤0.01	p≤0.001	p≤0.05	p≤0.05	p≤0.05	-	-	p≤0.05	p≤0.001	-	-	p≤0.01	-	-	p≤0.05	p≤0.05	-	-	-	p≤0.05	p≤0.05	p≤0.01	-											
thumbs	-	-	-	p≤0.01	p≤0.05	p≤0.001	p≤0.05	p≤0.05	-	-	-	p≤0.01	p≤0.01	-	p≤0.05	p≤0.01	p≤0.05	-	-	p≤0.05	-	-	-	p≤0.05	-	-	-	-										
fingers	p≤0.05	p≤0.05	-	-	-	p≤0.001	p≤0.05	-	-	p≤0.01	-	p≤0.001	p≤0.001	p≤0.05	-	p≤0.001	p≤0.01	p≤0.05	p≤0.05	-	p≤0.05	-	p≤0.05	-	p≤0.05	p≤0.05	p≤0.01	p≤0.01	p≤0.01									
palms	p≤0.05	p≤0.05	-	-	-	p≤0.001	p≤0.05	-	p≤0.05	p≤0.01	p≤0.05	p≤0.001	p≤0.001	p≤0.05	-	p≤0.001	p≤0.01	p≤0.01	p≤0.01	p≤0.05	p≤0.05	p≤0.05	p≤0.01	p≤0.05	p≤0.01	p≤0.05	p≤0.01	p≤0.01	p≤0.01	p≤0.05								
back hand	-	-	-	p≤0.01	p≤0.05	p≤0.001	p≤0.05	-	-	-	-	p≤0.01	p≤0.001	-	-	p≤0.001	p≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	p≤0.01	p≤0.01							
buttocks	-	-	-	p≤0.01	p≤0.05	p≤0.001	p≤0.05	p≤0.05	-	-	-	p≤0.01	p≤0.001	-	-	p≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	p≤0.01	p≤0.01	-						
sole	-	-	-	-	-	p≤0.001	p≤0.05	-	-	p≤0.05	-	p≤0.01	p≤0.001	-	-	p≤0.001	p≤0.01	-	-	-	-	-	-	-	-	-	p≤0.05	p≤0.05	p≤0.05	-	p≤0.01	-	p≤0.05					
top foot	-	-	-	-	-	p≤0.001	p≤0.05	-	-	p≤0.05	-	p≤0.01	p≤0.001	-	-	p≤0.001	p≤0.01	-	-	-	-	-	-	-	-	-	p≤0.05	p≤0.05	p≤0.05	-	p≤0.01	-	p≤0.05	-				
toes	-	-	-	-	-	p≤0.001	p≤0.05	-	-	p≤0.05	-	p≤0.01	p≤0.001	-	-	p≤0.01	p≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	p≤0.05	-	-			
heel	-	-	-	-	-	p≤0.001	p≤0.05	-	-	p≤0.05	-	p≤0.01	p≤0.001	-	-	p≤0.01	p≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	p≤0.05	-	-	-	-	-		
med. ankle	-	-	-	p≤0.01	p≤0.05	p≤0.001	p≤0.05	-	-	-	-	p≤0.05	p≤0.01	-	-	p≤0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	p≤0.01	p≤0.01	-	-	p≤0.01	p≤0.01	p≤0.05	p≤0.05	
lat. ankle	-	-	-	-	-	p≤0.001	p≤0.05	-	-	-	-	p≤0.01	p≤0.001	-	-	p≤0.01	p≤0.01	-	-	-	-	-	-	-	-	-	-	p≤0.05	p≤0.05	-	p≤0.05	-	p≤0.05	-	-	-	-	p≤0.001

p≤ 0.05	[mid grey]	p≤ 0.01	[light grey]	p≤ 0.001	[dark grey]

Supplemental Digital Content 3

Table 4. Significance level of comparison of absolute sweat rates for all regions measured at exercise intensity 2 after Bonferroni correction.

	shoulders	upper chest	med. upper bra	lat. upper bra	med. lower bra	lat. lower bra	bra triangle	lat. mid chest	med. mid chest	sides	ant. lower	lat. upper back	med. upper back	lat. mid upper back	lat. mid lower back	med. mid back	pos. lower back	ant. upper leg	med. upper leg	pos. upper leg	lat. upper leg	ant. lat lower leg	ant. med lower leg	pos. lower leg	ant. upper arm	pos. upper arm	ant. lower arm	pos. lower arm	thumbs	fingers	palms	back hand	buttocks	sole	top foot	toes	heel	med. ankle
upper chest	-																																					
med. upper bra	-	-																																				
lat. upper bra	-	-	-																																			
med. lower bra	-	-	-	-																																		
lat. lower bra	-	-	-	-	-																																	
bra triangle	-	-	-	-	-	-																																
lat. mid chest	-	-	-	-	-	-	-																															
med. mid chest	-	-	-	-	-	$	-	-																														
sides	-	-	-	$	-		-	-	-																													
ant. lower	-	-	-	-	-	-	-	-	-	-																												
lat. upper back	-	-	-		$		-			-	-																											
med. upper back							-			-	-	-																										
lat. mid upper back	-	-	-	-	-	-	-	-	-	-	-																											
lat. mid lower back	-	-	-	-	-	-	-	-	-	-	-	$		-																								
med. mid back	-	-	-		$		-		-	-	-	-	-																									
pos. lower back	-	-	-	-	-	$	-	-	-	-	-	-	-	-	-	-																						
ant. upper leg	-	-	-	-	-	$	-	-	-	-	-	-	$	-	-		-																					
med. upper leg	-	-	-	-	-		-	-	-	-	-	-		-	-		-	-																				
pos. upper leg	-	-	-	-	-	$	-	-	-	-	-	$		-	-		-	-	-																			
lat. upper leg	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-																		
ant. lat lower leg	-	-	-	-	-	-	-	-	-	-	-	-	$	-	-	$	-	-	-	-	-																	
ant. med lower leg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																
pos. lower leg	-	-	-	-	-		-	-	-	-	-	$		-	-		-	-	-	-	-	-	-															
ant. upper arm	-	-	-		-		-	-	-	-	-			-	-	$	-	-	-	-	-	-	-	-														
pos. upper arm	-	-	-	-	-		-	-	-	-	-	$		-	-	$	-	-	-	-	-	-	-	-	-													
ant. lower arm	-	-	-	-	-		-	-	-	-	-	-	$	-	-	-	-	-	-	-	-	-	-	-	-	-												
pos. lower arm	-	-	-	$	-	$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-											
thumbs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-										
fingers	-	-	-	-	-		-	-	-	-	-	-	$	-	-	$	-	-	-	-	-	-	-	-	-	-	-	-	-									
palms	-	-	-	-	-		-	-	-	-	-	$		-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-								
back hand	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
buttocks	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
sole	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
top foot	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
toes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
heel	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
med. ankle	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
lat. ankle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

p ≤ 0.05		p ≤ 0.01		p ≤ 0.001		0.1 < p ≥0.05	$

Supplemental Digital Content 4

Region		Skin Temperature (°C)				
		BL	**Pre I1**	**Post I1**	**Pre I2**	**Post I2**
UB	anterior upper	34.0	31.8***###	32.7***##	32.1**$	33.1*
	anterior bra (chest)	33.2	31.5***###	32.8***###	31.7***###	33.1***#
	anterior medial lower	32.7	30.3***###	31.8***##	29.8***###	31.2**#
	anterior lateral lower	33.2	31.3***##	32.4***##	31.1***###	32.1**$
	posterior medial upper	34.0	32.3***###	32.9***###	32.7	33.6**#
	posterior lateral upper	33.7	31.7***###	32.9***###	32.1***##	33.5***##
	posterior medial lower	33.4	31.8***###	32.8***##	32.1**#	33.4***##
	posterior lateral lower	32.8	31.1***###	32.2***##	31.1***##	32.5**#
	sides	32.8	31.5***###	32.2***#	31.5**#	32.4**#
Legs	anterior upper	30.7	30.3	31.9***###	30.8*	32.4**#
	medial upper	30.3	30.6	32.5**##	31.4**#	32.7*$
	posterior upper	30.8	30.9	32.5**##	31.2*	32.5**#
	lateral upper	30.7	30.8	32.7**##	31.6**$	33**#
	anterior lower	31.2	30.6	32.0**##	31.3*	32.5**#
	posterior lower	31.0	30.7	32.3**#	31.1*	32.5**##
AHF	anterior upper	32.7	30.7**#	32.4**#	30.9**#	32.4***##
	posterior upper	31.5	31.7	32.3	32.3	33.0*
	anterior lower	32.5	31.0*	32.5**#	31.2**#	32.6**#
	posterior lower	32.2	31.3	32.3*	32.1	33.0*
	palms	31.7	33.0	33.3	33.3	33.7
	hands	30.7	31.3	31.4	31.5	32.0
	heels	26.5	32.3***###	32.7	32.3	33.0
	soles	28.0	34.1***###	34.1	34.3	34.6
	dorsal foot	29.6	33.9***##	34.2	34.4	34.2
	ankles (anterior)	29.9	32.2*	33.0	32.1	32.7
	Mean	**31.7**	**31.5**	**32.6**	**31.8**	**32.9**
	SD	**1.9**	**1.0**	**0.6**	**1.1**	**0.7**

Table 1. Regional Skin Temperature at Baseline (BL), Pre, and Post Absorbent Pad Application at Exercise Intensity 1 and 2 in Female participants. Regional skin temperature significant from previous measurement period: * p<0.05, ** p<0.01, *** p<0.001 with no Bonferroni correction; # p<0.05, ## p<0.01, ### p<0.001 following Bonferroni correction.

		Skin Temperature (°C)				
Region		**BL**	**Pre I1**	**Post I1**	**Pre I2**	**Post I2**
UB	anterior medial upper	30.8	31.7	32.64*	32.5	33.9
	anterior lateral upper	30.8	31.1	32.01*	31.4*	33.2
	anterior medial lower	30.0	30.5	31.74*	30.1***##	32.5*
	anterior lateral lower	30.0	31.6	32.27*	31.3**#	33.0
	posterior medial upper	31.0	32.3	33.44**#	33.3	34.8
	posterior lateral upper	31.1	31.4	33.02**#	32.3*	34.3*
	posterior medial lower	29.4	32.4	33.27**$	33.2	34.5
	posterior lateral lower	29.4	31.4	32.63**#	32.0*	33.8
	sides	30.0	31.3	32.34**#	31.4*	33.1***###
Legs	anterior upper	31.1	31.4	32.2	32.4	32.8
	posterior upper	31.7	31.6	32.3**#	33.1	32.9
	lateral upper	31.0	31.3	32.1*	32.5	33.3
	anterior lower	31.5	31.2	31.5	32.2	31.9
	posterior lower	31.7	31.3	31.7	32.9	32.4
AHF	anterior upper	32.5	31.4	32.7**#	31.3**#	32.3**#
	posterior upper	31.8	31.6	32.7*	32.0	32.8**$
	anterior lower	31.5	31.6	32.9**#	32.1*	32.9*
	posterior lower	31.7	31.7	32.8*	32.4	33.0*
	palms	31.5	32.3	33.5	33.2	33.8
	hands	30.4	30.3	31.9	31.4	32.2
	heels	25.8	32.7**#	32.7	33.0	32.7
	soles	27.5	33.5***##	33.4	33.9	33.7
	dorsal foot	28.9	33.6**#	33.5	33.8	33.5
	ankles (anterior)	29.4	32.2*	32.5	32.2	32.2

Table 2. Regional Skin Temperature at Baseline (BL), Pre, and Post Absorbent Pad Application at Exercise Intensity 1 and 2 in Male participants. Regional skin temperature significant from previous measurement period: * $p<0.05$, ** $p<0.01$, *** $p<0.001$ with no Bonferroni correction; # $p<0.05$, ## $p<0.01$, ### $p<0.001$ following Bonferroni correction.