The effect of female breast surface area on heat-activated sweat gland density and output

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Introduction:

The production and evaporation of sweat from the skin surface is the human body's principal method of heat loss during heat stress. By 2 years of age, our skin contains 2-5 million sweat glands [1]. The number of sweat glands does not appear to change beyond this age. Hence, sweat gland density decreases with skin expansion during physical growth [1, 2].

In contrast to men, female development includes significant morphological changes across specific body parts, such as the breast. Female breast development, and the resulting breast surface area (BrSA), can vary greatly due to genetic factors, body-mass-index and energy intake early in life. However, it is unclear whether sweat gland density further decreases as breasts grow.

Sweat gland density may impact sweat output per gland for a given sweat rate [3]. This has implications for sweat accumulation in sport bras, which in turn affects breast heat balance and comfort during exercise heat stress in women of different breast sizes. This study aimed to investigate breast-size dependent, regional differences in sweat gland density and output during exercise heat stress in women with large differences in BrSA.

Method:

Fifteen healthy females (24±7yr) with large differences in BrSA (range=147.2-480.5cm^2) performed a 50-min submaximal run in a climatic chamber regulated at 33.0±0.8℃ and 53.4±2.0% RH. Sweat gland density (SGD; modified iodine technique [4]) and local sweat rates (LSR; absorbent patches [5]) were measured above and below the nipple, and at the bra triangle, during the final 5-min of exercise. Gastrointestinal (core) temperature and metabolic rate were monitored throughout the run. We used linear regression analyses to evaluate the relationship between: a) SGD and BrSA; and b) sweat output per gland (calculated as LSR/SGD) and BrSA. Furthermore, we assessed regional differences in SGD and sweat output per gland amongst the bra triangle, above and below the nipple, with a repeated-measures ANOVA.

Results:

SGD above (R^2=0.55, p<0.01, Fig. 1A) and below the nipple (R^2=0.63, p<0.01, Fig. 1B) decreased with increasing BrSA. This effect was not observed at the bra triangle (R^2=0.12, p=0.101, Fig. 1C). Sweat output per gland above the nipple increased with BrSA (R^2=0.29, p=0.02, Fig. 2A). This effect was not observed below the nipple (R^2=0.13, p=0.10, Fig. 2B) nor at the bra triangle (R^2=0.04, p=0.24, Fig. 2C).

SGD was lower at both breast sites (above nipple=35.6±6.0 glands/cm^2; below nipple=31.2±4.8 glands/cm^2, $p<0.01$) than at the bra triangle (86.8±5.3glands/cm^2, Fig. 3). Sweat output per gland above (343.4±39.6µg, $p<0.01$), but not below (416.4±62.5µg, $p=0.89$), the nipple was lower than at the bra triangle (690.6±76.0µg, Fig. 4).

Conclusion:

Our findings indicate that SGD decreases and sweat output per gland increases with increasing BrSA, and that SGD and output per gland vary greatly across the breast and bra triangle. It therefore appears that, to maintain breast heat balance, individual sweat glands upregulate their activity to accommodate their lower density across larger breasts. Sport bra design may therefore consider the implications of this on sweat accumulation patterns for women of different breast, thus bra sizes.

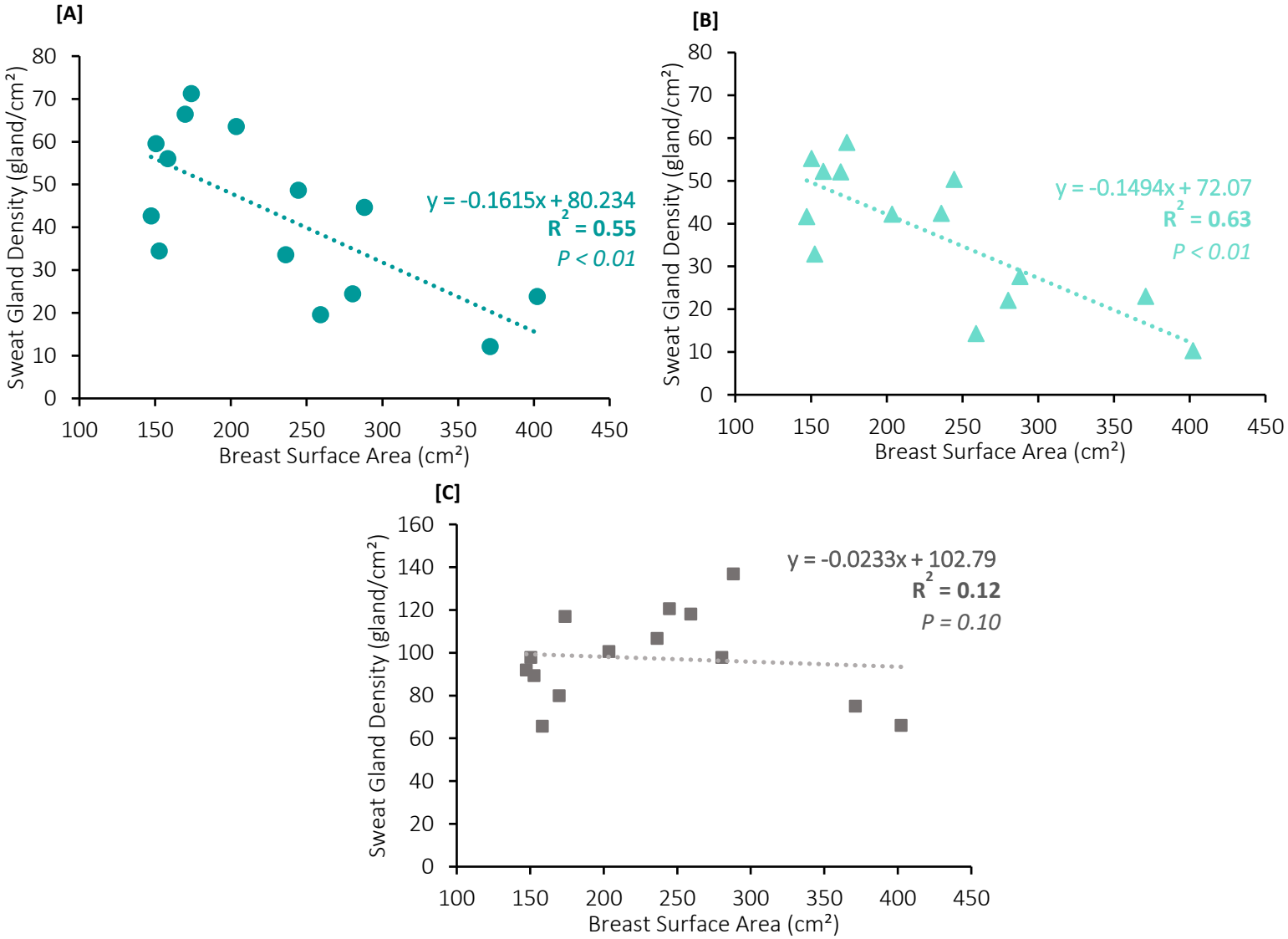

Figure 1. Relationship between breast surface area and sweat gland density at 3 chest locations (n=15). [A] Above Nipple. [B] Below Nipple. [C] Bra Triangle. Significant negative correlations between breast size and sweat gland density above the nipple and below the nipple ($p < 0.05$).

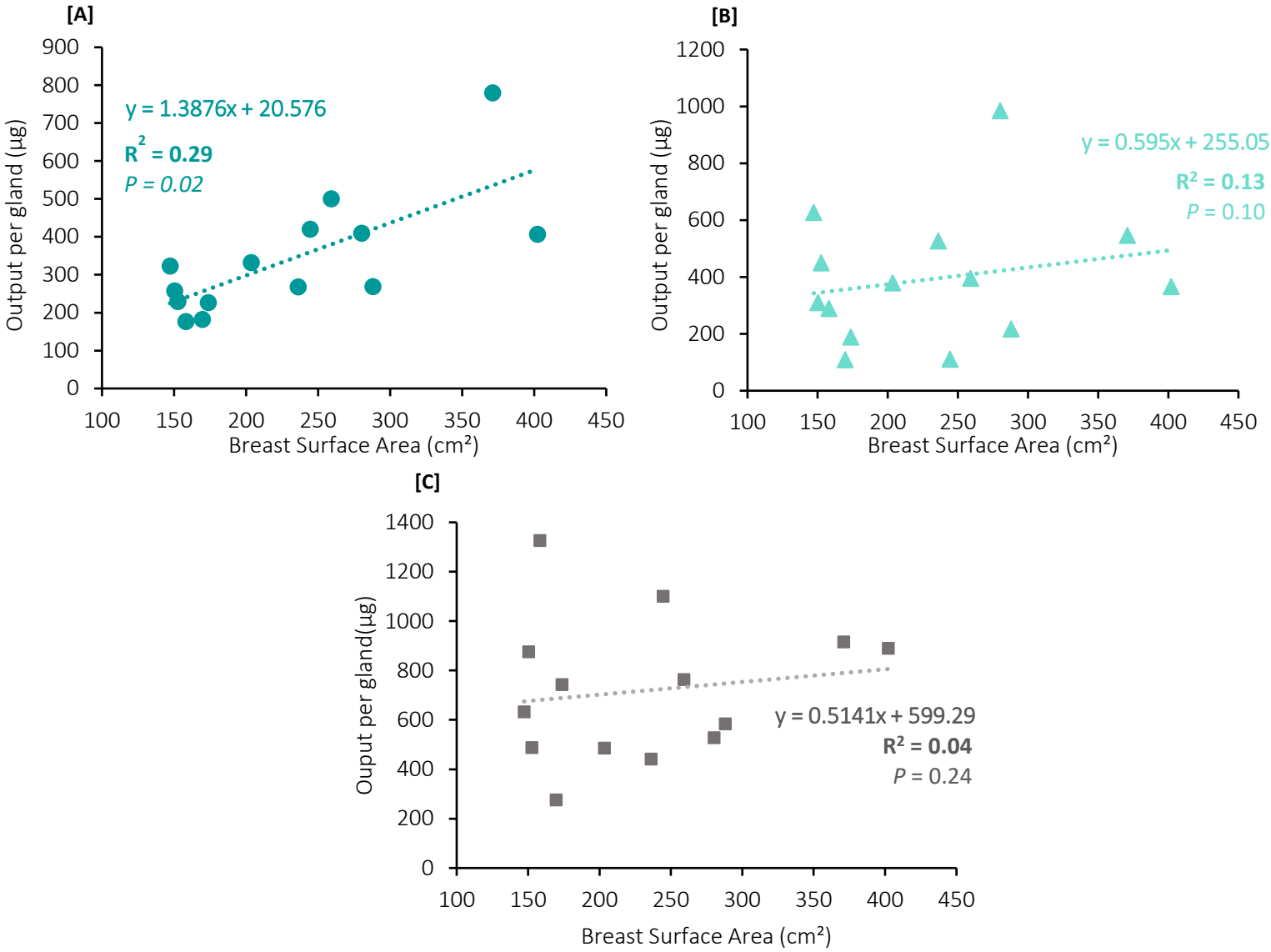

Figure 2. Relationship between breast surface area and sweat output per gland at 3 chest locations (n=15). [A] Above Nipple. [B] Below Nipple. [C] Bra Triangle. Significant positive correlation between breast surface and sweat output per gland above the nipple ($p < 0.05$).

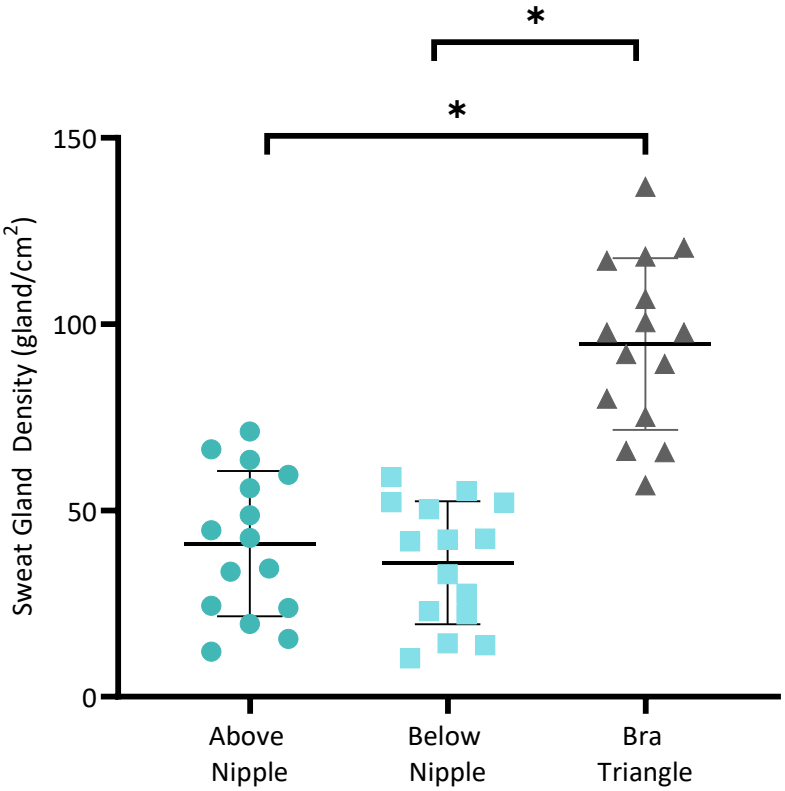

Figure 3. Sweat gland density regional differences from 3 chest locations. Mean±SD. *denotes statistically significant difference in total average SGD between test site locations, $p < 0.05$.

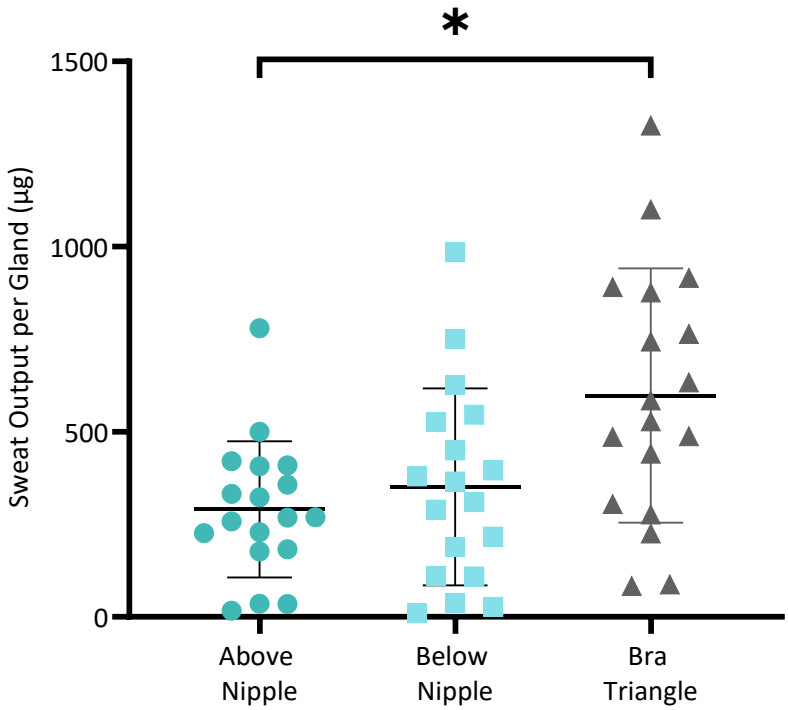

Figure 4. Sweat output per gland regional differences from 3 chest locations. Mean±SD. *denotes statistically significant difference in sweat output per gland between test site locations, $p < 0.05$.

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