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BRIEF COMMUNICATION

Gender Differences in Facial Skin Blood Perfusion during Basal and Heated Conditions Determined by Laser Doppler Flowmetry

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INTRODUCTION

Skin blood perfusion data as assessed by laser Doppler methods have provided useful information with regard to physiological (Cooke *et al.*, 1990; Tenland *et al.*, 1983; Tur *et al.*, 1983) and pathophysiological features of skin circulation (Creutzig *et al.*, 1987; Malvezzi *et al.*, 1992; Rendell *et al.*, 1989, 1992; Tooke *et al.*, 1987; Hassan *et al.*, 1986). These and other human studies have provided characterizations of limb skin perfusion in normals and in patients with compromised circulations using baseline perfusion levels and dynamics as well as the responses to various perturbations. In addition, a number of anatomical sites have been studied to discern the effects of external factors on skin perfusion (Tur *et al.*, 1985; Nilsson *et al.*, 1986; Smolander *et al.*, 1987; Sagawa *et al.*, 1992; Mayrovitz and Larsen, 1992; Mayrovitz *et al.*, 1992). A site that has received very little attention is the skin of the face. Data concerning normal basal facial skin perfusion levels, subject-to-subject variability, responses to heat load, and gender related differences in perfusion are among the areas essentially absent from the literature. The purpose of this communication is to present initial basic data on facial skin perfusion characteristics as determined in 10 subjects (five male and five female) prior to, during, and following contact heating of the face.

METHODS

Study Population

Ten subjects (five male and five female) in the age range from 25 to 52 years participated in this study. No subject had diabetes or, by history, any other known condition which might effect skin blood flow. All subjects were nonsmokers and were free of facial hair or facial pathology. Males were asked not to shave for at least 2 hr prior to testing and females were asked not to wear facial makeup.

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Each subject was informed of the nature of the study and read and signed an approved informed consent.

Protocol

Testing was conducted in an environment which was controlled to exclude external stimuli and room temperature fluctuations, only soft background music was played. Blood pressure measurements prior to and after the testing procedure established that no subject was hypertensive.

The protocol sequence began with the subject supine. Blood pressure and heart rate were measured. Thereafter, the right cheek was gently cleansed using a cotton ball and facial cleanser. A laser Doppler flow probe (Vasamedics Inc., Model PD-434) was affixed to the right cheek with double-sided tape, and adjacent to the flow probe, a small thermistor (Baily BAT-8) for measuring skin temperature was placed. Following probe placement, the subject underwent an additional 10-min undisturbed acclimation interval. During this preheating, baseline interval skin blood perfusion (Vasamedics Inc., Model BPM2) and skin and room temperatures were digitally displayed and recorded every 2 min. Following this, a warm (44°, degrees C) moist towel was applied to the face. An electrically heated and controlled temperature face mask (kindly supplied by Questech International Inc., Tampa, FL), which had been preheating for 12 min, was then placed over the towel and secured via velcro straps to the back of the head. With the mask secured in position, the average surface temperature of the mask was determined with two additional thermistors securely taped to its surface. This mask–towel interface temperature averaged 45° over the heating interval. The mask–towel combination covered the face and forehead with an opening for the nose. During the heating interval there was an approximate 8° temperature differential between the mask–towel interface and the towel–skin interface. Skin blood perfusion and skin and room temperatures were recorded every 2 min during the facial heating interval. After 12 min of facial heating, the mask and towel were removed, and measurements of blood perfusion and skin and room temperatures were recorded every 5 min during a 1-hr recovery interval. At the end of the 1-hr interval, blood pressure was again measured.

Instrumentation

Facial skin blood perfusion was measured using laser Doppler methods using the Vasamedics Model BPM2 system. This system provides three separate direct readouts proportional to mean tissue blood flow, and red cell circulating volume and velocity within the sampled tissue volume (approximately 1 mm^3). As differentiated from earlier systems, in which these quantities were reported in basic units of either volts or frequency deviations, the model used in the present study has incorporated conversion factors so that flow is reported in milliliters per minute per 100*g*, volume as the percentage of the sampled volume which is moving red cells, and velocity in millimeters per second. Though the range and conditions over which these conversions are applicable are still incompletely resolved, their use in the present setting is at least as adequate as using relative units.

Statistical Comparisons

Facial parameter measurements (skin flow, volume, velocity, and temperature) were treated as repeated measures, and testing for overall differences between

TABLE 1
SUBJECT BASELINE VALUES

Subject	Flow	Volume	Velocity	T_{skin}	Age	Sex	Sys	Dia	HR
03	5.3	1.6	0.9	33.1	25	F	130	80	88
10	6.6	1.1	1.8	31.9	49	F	130	70	66
05	7.5	1.4	1.6	33.6	42	F	140	86	78
04	8.5	1.6	1.6	35.1	36	F	104	78	68
07	8.8	1.3	2.0	31.4	36	F	110	85	56
08	9.3	1.9	1.5	32.8	52	M	122	84	60
06	9.4	1.7	1.6	34.1	27	M	140	82	68
09	10.1	1.5	2.0	31.6	51	M	142	84	64
02	12.0	1.9	1.9	33.5	27	M	148	68	61
01	16.4	1.9	2.3	32.6	34	M	122	72	66

Note. Subjects are listed in order of increasing flow. Flow (ml/min/100g), volume (%), velocity (mm/sec), and skin temperature (T_{skin}, deg C) are the average of five baseline values obtained at 2-min contiguous intervals. Heart rate (HR, bpm) and systolic (Sys) and diastolic (Dia) blood pressure (mm Hg) were measured once at the beginning of baseline.

genders was done using multivariate analysis of variance (MANOVA) with a level of $P < 0.05$ being considered statistically significant. Separate analyses were carried out for the baseline preheating interval, the heating interval, and the recovery phase. Other baseline parameters (age, blood pressure, and heart rate) were compared using t tests for independent samples, and comparisons of change in blood pressure and heart rate were made using t tests for dependent samples.

RESULTS

Baseline Levels

The preheating baseline values for each subject are listed in Table 1 in ascending order of flow. All female subjects are noted to have flow values in the lower half of the overall flow range. Comparisons of gender differences (Table 2) show that mean flow and volume but not velocity are significantly greater in the males. Also as shown in Table 1, facial skin temperatures are nearly identical. This indicates that the gender flow differences are not due to temperature effects. Nor, as shown by the following data, are these flow differences explainable due to gender group differences in age, blood pressure, heart rate, or in the room temperature during

TABLE 2
GENDER FACIAL PARAMETER COMPARISONS AT BASELINE

	Flow		Volume		Velocity		Tskin	
	M	F	M	F	M	F	M	F
Mean	11.4	7.0	1.8	1.4	1.9	1.6	32.9	33.0
SD	2.8	1.6	0.2	0.3	0.3	0.4	0.9	1.5
P	0.021		0.037		0.236		0.901	

Note. Gender comparisons based on MANOVA with time as a repeated measure. Mean, average value during baseline interval; $n = 5$ for females and $n = 5$ for males. Units as in Table 1.

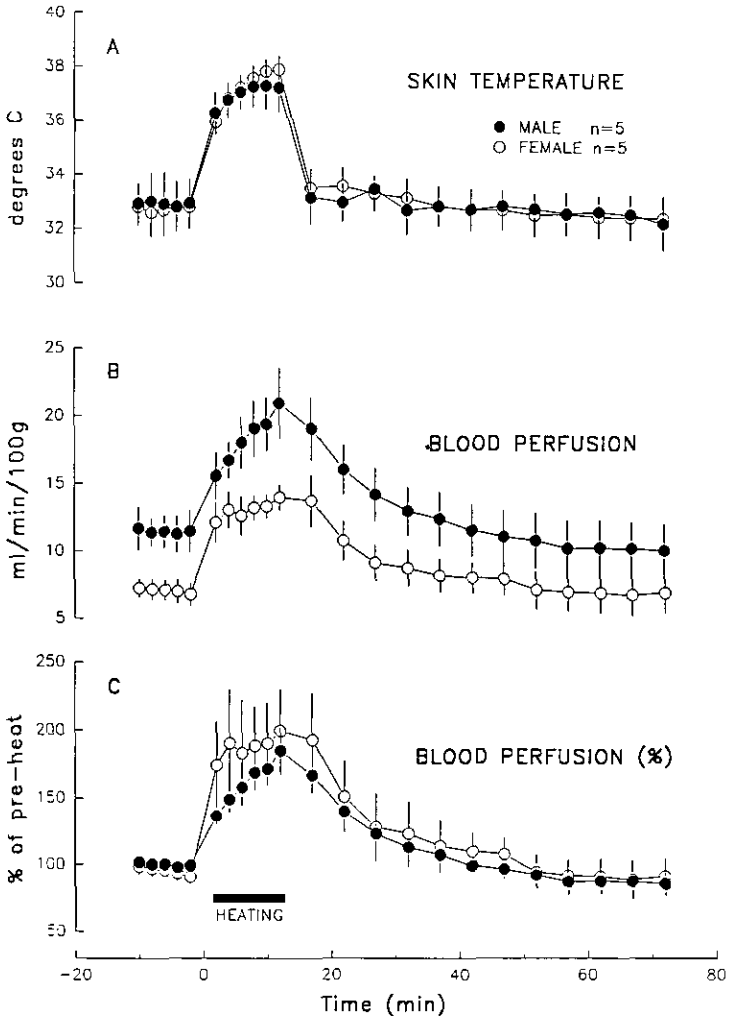

FIG. 1. Temporal response to 12 min of facial contact heating. Error bars are S.E.M. (A) Skin temperature; (B) Skin blood perfusion; (C) Blood perfusion expressed as a percentage of the preheating baseline average perfusion.

the test, as all of these showed no gender group differences. These measured parameters were (mean ± SD) for males vs females, respectively: age, 38.2 ± 12.5 vs 37.2 ± 9.0 years (P = 0.888); systolic blood pressure, 135 ± 12 vs 123 ± 15 mm Hg (P = 0.200); diastolic blood pressure, 78 ± 7 vs 80 ± 6 mm Hg (P = 0.762); heart rate, 64.4 ± 2.9 vs 71.2 ± 12.0 bpm (0.261); and room temperature, 21.6 ± 0.6 vs 22.2 ± 1.3° (P = 0.394).

Response to Facial Heating

Figure 1A shows the time course of the skin temperature change for each gender group. The average skin temperatures during the heating interval did not differ

TABLE 3
GENDER COMPARISONS DURING THE HEATING INTERVAL

Parameter	Flow		Volume		Velocity		T_{skin}	
	M	F	M	F	M	F	M	F
	Machine units							
Mean	18.3	13.0	2.2	1.9	2.4	2.0	36.9	37.2
SD	4.4	2.5	0.2	0.4	0.5	0.1	0.8	1.1
P	0.038		0.187		0.090		0.620	
	Percentage of baseline average							
Mean	162	188	125	138	130	138	112	113
SD	29	68	8	18	16	42	3	5
P	0.329		0.221		0.590		0.690	

Note. Machine units are ml/min/100*g* for flow; volume percentage for volume; and mm/sec for velocity. Mean, average of preheating baseline levels; SD, standard deviation. Gender statistical comparisons based on MANOVA with time as a repeated measure; $n = 5$ for males and $n = 5$ for females. Percentages are rounded to the nearest whole number.

between gender groups (Table 3). However, in females the skin temperature tended to increase during the entire heating interval whereas with males the skin temperature tended to plateau after 6 min of heating. As shown in Fig. 1B, the pattern of the flow response in females was characterized by a rapid rise to near maximum levels followed by a plateau at the maximum. Contrastingly, in males the flow continued to increase during the heating interval in a near linear fashion. The average flow in males significantly exceeded that in females during the heating interval as shown in Table 3. The maximum flow of males during the heating interval was 20.9 ± 5.8 (mean ± SD) as compared with 14.0 ± 2.1 for females. The flow response, expressed as a percentage of average preheating levels (Fig. 1C), shows that the female percentage change tended to be greater than that in males although the difference in average percentage increase during the heating interval was not significant in flow, volume, or velocity, as shown in Table 3.

Recovery Phase

After heat mask removal, skin temperature decreased rapidly and by 5 min into the recovery phase, the skin temperature was close to preheating levels in both gender groups (Fig. 1A). A gradual further decline in temperature was noted over the 60-min observation interval. Blood flow recovery was less rapid (Figs. 1B and 1C) and remained above the average preheating level for about 15–20 min. Flow continued to decline and by the end of the 60-min interval, flow was near preheating levels. The average levels for each measured facial parameter over the entire recovery interval were not significantly different between genders. Blood pressures and heart rate measured at the end of the test were similar to baseline values with no significant differences from baseline or between gender groups.

DISCUSSION

The present study was designed to provide basic information on facial skin blood perfusion in females and males under resting baseline conditions and during and following moderate contact heating of the entire face.

Baseline

Regarding the baseline features, the present findings show a consistently lower facial skin blood perfusion in females. This gender difference in flow is not due to differences in blood pressure or skin or room temperature, but arises primarily due to a lower value in the laser Doppler determined volume parameter, whereas the average velocity of the red cells was not significantly different between genders. Since the volume parameter is proportional to the volume density of moving red blood cells in the sampled tissue volume, this result could be a consequence of either fewer microvascular flow channels per unit tissue volume with flowing cells or a smaller number density of red cells perfusing the tissue. The latter possibility may explain some of the difference in that the systemic hematocrit in females tends generally to be less than that in males. However, the overall average flow difference between genders (males 56% greater than in females) is unlikely fully explained by hematocrit differences. Indeed, Cooke and co-workers (1990) demonstrated that in males, hand blood flow under basal conditions was 95% greater than that in females (12.1 vs 6.2 ml/min/100*g*) and that finger skin perfusion measured with laser Doppler had an even greater gender difference. Forearm gender differences have also been described (Bartelink *et al.*, 1990). The present results extend these findings by showing that such gender differences are also present in the facial skin. Further, by virtue of the simultaneous volume measurements in the present study, a gender difference in the number density of microvessels with active flow is suggested as a mechanism to at least in part explain the basal flow difference. This mechanism would be consistent with the concept of a larger basal sympathetic tone in females. However, despite the differences in flow magnitude between gender groups, the baseline data show that the flow ranges within gender groups are remarkably similar. Expressed as the ratio of highest to lowest subject's baseline flow, these are 1.67 for females and 1.76 for males.

Heating Response

The magnitude and time course of the flow response during the heating interval are different in males and females. The magnitude of the flow during heating was greater in males and is accountable for mainly due to the higher level of basal flow. On the basis of the percentage increase from baseline, the average increase actually tended to be marginally greater in females but with no significant gender differences being detected. Similar responses were noted by others (Cooke *et al.*, 1990) who found that upon local heating of the hand to 42°, flow in both males and females increased but the female average heated levels were less than those in the male group (male 20.7, female 16.9 ml/min/100*g*) but with a greater percentage increase in females. Aside from the magnitude differences, the present study reveals a temporal response pattern which is visually different between gender groups. Flow in males continued to increase during the heating interval

whereas in females the flow rapidly reached a near plateau and remained there throughout the heating interval. The physiological mechanism responsible for this apparent difference in temporal response is as yet uncertain. The time courses of the postheating recovery phase were similar between genders and were characterized by a rapid return of skin temperature to preheated levels and a more gradual decrease in skin perfusion. The perfusion remained above preheated levels for about 15–20 min and thereafter could not be statistically distinguished from baseline levels.

The present findings show that baseline facial skin perfusion in females is significantly less than that in males principally due to a smaller number of perfused microvessels. Facial contact heating, though causing a perfusion increase in both genders, fails to diminish this gender flow difference, although each group responds with similar percentage increases. These findings point out the importance of taking into account gender differences when skin perfusion features are used in either physiologic studies or clinical assessment protocols. The data presented provide preliminary information as to the nature of the expected gender differences and anticipated flow ranges for cheek skin blood perfusion.

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