CUTANEOUS RESPIRATION IN MAN

IV. The Rate of Carbon Dioxide Elimination and Oxygen Absorption in Normal Subjects[1]

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Shaw and his associates (1, 2) demonstrated that the rate of cutaneous respiration in man is influenced principally by the temperature and humidity of the air in contact with the skin and by individual characteristics of different subjects. The present investigation was undertaken to establish the range of carbon dioxide elimination and oxygen absorption through the skin in normal individuals of various ages under controlled conditions of temperature and relative humidity.

METHOD OF STUDY

The apparatus and technical procedure were essentially the same as those employed by Shaw and Messer (2) in studying the effect of temperature on the rate of cutaneous respiratory exchange. The subject lay on a bed with the entire arm in a glass plethysmograph filled with room air kept at the saturation point by means of a moist woolen stocking worn on the arm. The temperature within the plethysmograph varied between 26° C. and 31° C. in different experiments but was maintained practically constant during individual experiments by regulating the temperature of the room. All experiments were made with the room temperature between 20° C. and 26° C.

After a preliminary mixing period of 20 minutes, a sample of gas was withdrawn from the plethysmograph. Three hours later a second sample was collected. The change in percentage concentration of carbon dioxide and oxygen multiplied by the total volume of gas in the system gave the volume of carbon dioxide or oxygen which had been gained or lost. All quantities were corrected to standard conditions of temperature and barometric pressure, and the rates of carbon dioxide excretion and oxygen absorption were expressed in terms of cubic centimeters per hour per square meter of skin surface. In order that the results obtained in different individuals should be comparable, all final quantities were transposed by interpolation to the value they would have had if the

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temperature of the air in the plethysmograph had been 27° C. This was done in the following manner. In each subject on whom three or more measurements of the rate of cutaneous respiration were made, the rates of carbon dioxide elimination and oxygen absorption in each experiment were plotted against the temperature of the air in the plethysmograph during that observation (Figure 1). Average straight lines were then con-

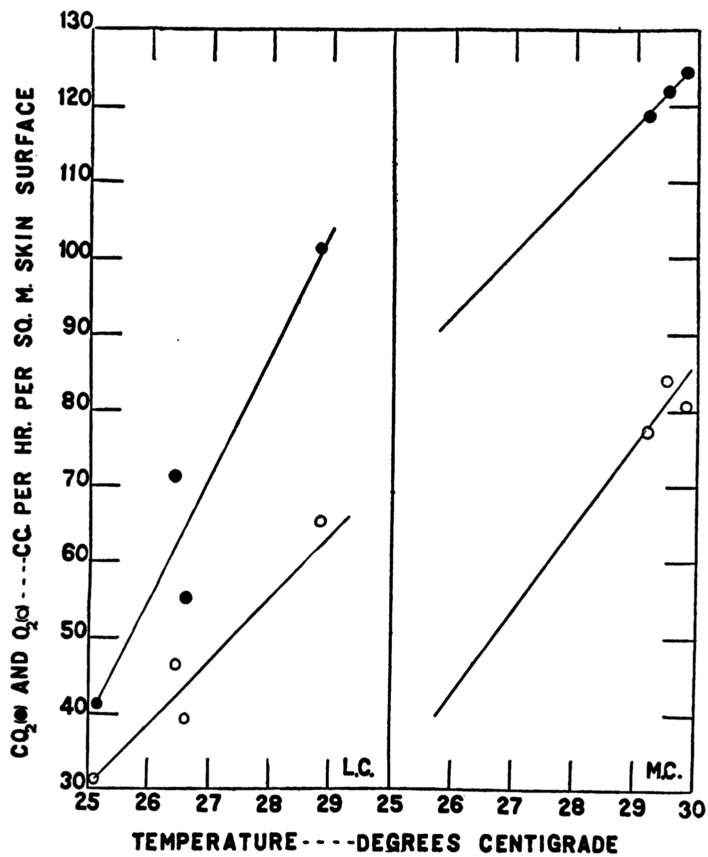

FIG. 1. ILLUSTRATES THE METHOD FOR TRANSPOSING THE OBSERVED VALUES FOR CUTANEOUS RESPIRATION TO THEIR VALUES AT 27° C.

Each charted point represents the rate of carbon dioxide elimination or oxygen absorption observed at the indicated temperature. The data obtained in two patients are presented and demonstrate the individual variations in the effect of temperature on cutaneous gas exchange in normal subjects.

structed from the charted points. Shaw and Messer (2) have demonstrated that at temperatures below 34° C. the rate of cutaneous respiration varies directly with the temperature of the air in contact with the skin. The rate of gas exchange through the skin at 27° C. in our subjects, therefore, was indicated by the height of the constructed lines at 27° C. In those subjects on whom only two measurements of cutaneous respiration were made, the results were transposed to their value at 27° C. by using the average correction per degree rise in temperature for the entire group.

The rate of cutaneous respiration was measured on three or more occasions in the majority of the subjects, the observations on each individual being made on successive days whenever possible. In 20 subjects, two or more experiments were made under practically identical conditions of temperature. In four individuals, the rate of cutaneous respiration in the two arms was compared; and in three, measurements were repeated at intervals over a period of two to several months. All observations were made between November 1, 1930 and June 2, 1931.

In 17 subjects, the rate of oxygen absorption through the lungs was determined during the estimation of the rate of cutaneous respiration.

RESULTS

One hundred and twenty-one measurements of the rate of cutaneous respiration were made in 38 individuals between the ages of 15 and 75 years. Twelve of the subjects were females and 26 were males. The arterial blood pressure was within the limits of normal in all, and none presented lesions of the skin or evidence of respiratory, circulatory or metabolic disturbances. The erythrocyte count and hemoglobin content of the blood were within the limits of normal in all. A few of the elderly individuals showed slight to advanced sclerosis of the peripheral arteries.

The range of cutaneous respiration in normal subjects. A summary of the observations on each subject together with the maximum, minimum and average values recorded for the entire group are presented in Table 1. The rate of carbon dioxide elimination per hour per square meter of skin surface at 27° C. varied in different individuals from 58 cc. to 169 cc. with an average value of 120 cc. The rate of oxygen absorption per hour per square meter of skin surface at 27° C. averaged 88 cc. and varied in different individuals from 40 cc. to 146 cc. The respiratory quotient of cutaneous gas exchange at 27° C. averaged 1.4 and varied between 1.1 and 2.0.

Frequency distribution diagrams of the values for carbon dioxide elimination, oxygen absorption and respiratory quotient are presented in Figures 2 and 3. In 31 of the 38 subjects, the rate of carbon dioxide elimination varied between 100 cc. and 150 cc. per hour per square meter of skin surface, while in 29 individuals the rate of oxygen absorption varied between 60 cc. and 120 cc. per hour per square meter of skin surface. In 26 subjects, the respiratory quotient was between 1.2 and 1.6.

Variations in the effect of temperature on the rate of cutaneous respiration. The increase in carbon dioxide elimination with each degree rise in

TABLE 1

Cutaneous respiration in normal subjects at 27° C.

Subject	Sex	Age	CO_2 excreted		O_2 absorbed		$\frac{CO_2}{O_2}$	Temperature in plethysmograph		
			Per hour per square meter	Increase per degree rise in temperature‡	Per hour per square meter	Increase per degree rise in temperature‡		Experiment 1	Experiment 2	Experiment 3
		years	*cc.*	*cc.*	*cc.*	*cc.*		*° C.*	*° C.*	*° C.*
1	F	15	117		74		1.6	29.0	29.0	27.5
2	M	15	118		82		1.4	26.3	27.4	
3	M	16	128		63		2.0	29.8	28.2	
4	F	17	134		87		1.5	29.9	30.0	
5	F	17	129		100		1.3	27.8	29.0	
6	M	19	142	4	96	5	1.5	29.2	27.6	28.9
7	M	19	143		116		1.2	30.8	29.4	
8	M	20	130	13	91	12	1.4	29.3	28.5	30.2
9	F	22	140	9	100	8	1.4	28.1	29.6	26.9
10	F	22	169	16	146	17	1.2	27.5	24.3	28.6
11	F	22	140	16	121	18	1.2	26.7	27.6	26.4
12	M	23	100	2	59	3	1.7	27.5	27.9	
13	F	24	93	1	64	2	1.5	29.2	29.9	29.5
14	M	24	107	4	84	4	1.3	29.0	28.4	28.2
15	M	24	103		85		1.2	30.0	28.8	29.1
16	M	24	101		76		1.3	26.5	26.6	28.4
17	F	24	131	7	119	7	1.1	28.1	30.4	27.2
18	F	24	143	18	115	16	1.2	28.3	27.6	25.9
19	M	24	156		138		1.1	29.6	28.4	27.7
20	M	25	147	5	110	4	1.3	29.8	28.0	28.6
21*	M	26	58	5	40	4	1.5	26.7	27.7	28.8
22	F	30	104	6	75	8	1.4	27.9	27.2	28.0
23	M	30	135	2	89	7	1.5	29.2	27.6	28.6
24	M	33	129	11	111	6	1.2	27.0	28.1	
25	M	35	129	7	77	7	1.7	29.1	30.0	
26	M	36	139	3	125	4	1.1	30.0	30.2	29.3
27	M	44	84	8	54	2	1.6	31.4	30.3	28.9
28	F	45	127	7	83	6	1.5	27.2	28.6	
29†	M	48	72	15	48	9	1.5	26.6	26.4	25.1
30†	M	50	106	5	55	7	1.9	29.4	29.7	
31†	M	50	120	14	65	17	1.9	28.9	30.3	
32	F	51	136	10	118	15	1.2	27.5	26.2	27.3
33†	M	53	101	6	81	6	1.2	27.8	29.6	28.3
34	M	57	109	5	60	7	1.8	29.2	29.8	29.5
35	M	61	124	6	75	5	1.7	28.4	28.4	29.5
36†	M	64	117	14	96	5	1.2	27.8	27.7	
37†	M	70	118		81		1.5	26.3	29.0	
38†	M	75	95	11	81	8	1.2	28.5	28.6	
Maximum value			169	18	146	18	2.0			
Minimum value			58	1	40	2	1.1			
Average value			120	8	88	8	1.4			

* From Shaw and Messer (2).

† Subjects having moderate or advanced arteriosclerosis.

‡ The increase in the rate of carbon dioxide elimination and oxygen absorption per degree rise in the temperature of the air in contact with the skin is given

temperature of the air in contact with the skin averaged 8 cc. per hour per square meter of skin surface and varied in different subjects from 1 cc. to 18 cc. (Table 1). The increase in oxygen absorption with each degree rise

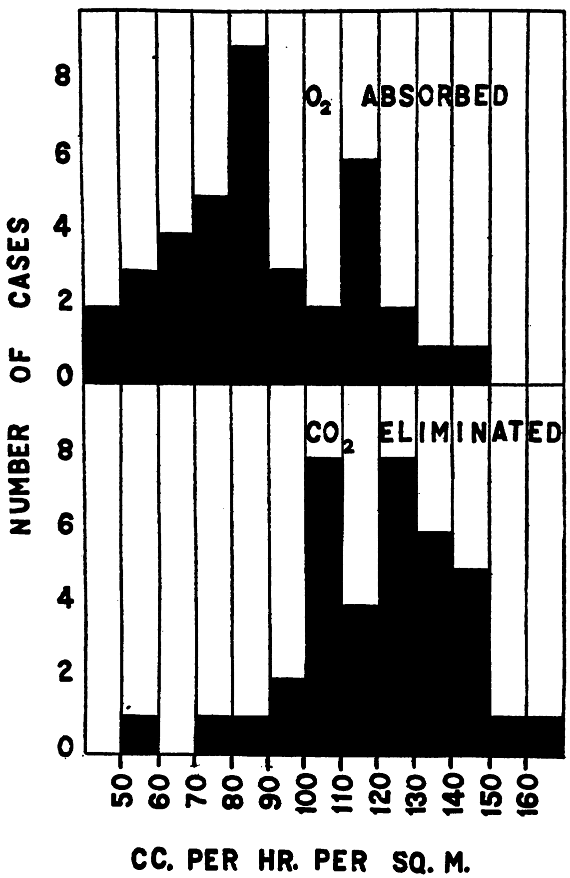

FIG. 2. FREQUENCY DISTRIBUTION DIAGRAMS OF THE VALUES FOR CARBON DIOXIDE ELIMINATION AND OXYGEN ABSORPTION AT 27° C. IN NORMAL SUBJECTS

in temperature of the air in contact with the skin varied in different subjects from 2 cc. to 18 cc. with an average value of 8 cc. per hour per square meter of skin surface.

Variations in repeated measurements of the rate of cutaneous respiration in the same individual. In those subjects in whom two or more measure-

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for those subjects in whom three or more measurements of the rate of cutaneous respiration were made. In those subjects on whom only two measurements were made, the results were transposed to their value at 27° C. by using the average correction per degree rise in temperature for the entire group.

ments of cutaneous respiration were made under practically identical conditions of temperature, small but significant variations were recorded (Table 2). The average variation in the amount of carbon dioxide eliminated was ± 3 cc. per hour per square meter of skin surface, and the maximum variation was ± 10 cc. The average variation in the amount of oxygen absorbed was ± 5 cc. per hour per square meter of skin surface, and the maximum variation was ± 15 cc. The average variation in the respiratory quotient was ± 0.1, and the maximum variation was ± 0.3.

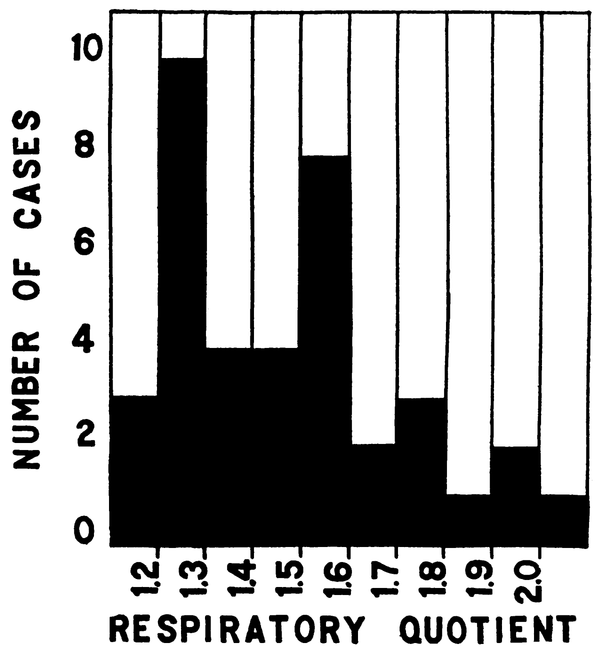

FIG. 3. FREQUENCY DISTRIBUTION DIAGRAM OF THE VALUES FOR RESPIRATORY QUOTIENT AT 27° C. IN NORMAL SUBJECTS

Rate of cutaneous respiration in the two arms. No constant difference was observed in the rate of cutaneous respiration in the two arms (Table 3).

Effect of season on the rate of cutaneous respiration. In the subjects on whom measurements of cutaneous respiration were repeated at intervals over a period of two to eight months, no evidence of seasonal variations in the rate of carbon dioxide excretion and oxygen absorption was observed (Table 4).

Effect of sex on the rate of cutaneous respiration. No constant difference in the rate of cutaneous respiration was observed in the two sexes (Table 1).

Effect of age on the rate of cutaneous respiration. The rate of carbon dioxide elimination and oxygen absorption tended to be greater in individuals below the age of 40 years than in those above that age (Table 5). In the subjects over the age of 40 years, the rate of cutaneous respiration tended to be lower in individuals having moderate or advanced

TABLE 2

Variations in the rate of cutaneous respiration under practically identical conditions of temperature and humidity*

Subject	Variation in CO_2 excreted	Variation in O_2 absorbed	Variation in respiratory quotient	Temperature in plethysmograph
	cc. per hour per square meter	*cc. per hour per square meter*		*° C.*
1	± 1	± 4	± 0.1	29.0
4	± 3	± 15	± 0.2	30.0
6‡	± 6	± 9	± 0.1	30.0
11	± 3	± 6	± 0.0	26.6
12	± 0	± 2	± 0.0	27.7
13†	± 0	± 13	± 0.3	29.5
14	± 1	± 2	± 0.0	28.3
15	± 1	± 0	± 0.0	29.0
16	± 10	± 8	± 0.0	26.6
22	± 3	± 13	± 0.3	28.0
23‡	± 3	± 0	± 0.0	29.8
26	± 0	± 8	± 0.1	30.1
29	± 8	± 4	± 0.1	26.5
30	± 5	± 1	± 0.0	29.6
32	± 7	± 4	± 0.0	27.4
33	± 3	± 0	± 0.0	28.1
34†	± 3	± 3	± 0.1	29.5
35	± 7	± 4	± 0.0	28.4
36	± 2	± 1	± 0.0	27.8
38	± 1	± 10	± 0.1	28.6
Average	± 3	± 5	± 0.1	

* The maximum difference in temperature in the plethysmograph during the two (or three) experiments on one subject was 0.5° C. The temperatures given in the table represent the average for the two (or three) measurements on each individual.

† Indicates that the figures given are for the maximum variations observed in three experiments. All other figures are for the variations observed in two experiments.

‡ Indicates that the interval between the collection of samples was two hours instead of three.

generalized arteriosclerosis than in those presenting slight or no evidence of arteriosclerosis (Table 6). These relations were not exact in individual instances.

Relation between the rate of respiratory exchange through the lungs and the rate of cutaneous respiration. In 17 subjects, the average amount of oxygen absorbed through the lungs was 7.78 liters per hour per square meter of body surface. At 32° C., the approximate normal temperature of the skin, the average calculated amount of oxygen absorbed through the skin in these individuals was 152 cc. per hour per square meter, or 1.9 per cent of that absorbed through the lungs. In individual subjects no precise relationship was observed between oxygen absorption through the lungs and oxygen absorption through the skin.

TABLE 3

Comparisons of the rate of cutaneous respiration in the two arms *

Subject	CO_2 excreted		O_2 absorbed		Remarks
	Right arm	Left arm	Right arm	Left arm	
	cc.	*cc.*	*cc.*	*cc.*	
6...	146	139	98	95	Values for right arm are the average of five experiments; those for the left arm the average of seven measurements
9...	135	142	87	105	Values for right arm are the average of three experiments; those for the left arm the average of six measurements
22...	101	106	90	66	Values for right arm are the results of one experiment; those for the left arm the average of two measurements
23...	143	129	94	84	Values for right arm are the average of three experiments; those for the left arm the average of four measurements

* Calculated in cubic centimeters per hour per square meter of skin surface at 27° C.

If it is assumed that the average quotient of respiratory exchange through the lungs in the above subjects was 0.82, then the average calculated amount of carbon dioxide excreted through the lungs was 6.37 liters per hour per square meter of body surface. At 32° C. the average amount of carbon dioxide excreted through the skin in these individuals was 175 cc. per hour per square meter, or 2.7 per cent of that excreted through the lungs. In individual subjects no precise relationship was observed between the amount of carbon dioxide eliminated through the lungs and the amount excreted through the skin.

DISCUSSION

Mechanism of cutaneous respiration. The total gaseous exchange through the skin is the result of two distinct processes: (1) the metabolism of the skin, and (2) the passage of carbon dioxide out of the blood by diffusion through the skin (1). The fact that the respiratory quotient is always above unity, with an average value of 1.4 in our subjects, indicates

TABLE 4

The effect of season on the rate of cutaneous respiration *

Subject	Date	CO_2 excreted	O_2 absorbed	$\frac{CO_2}{O_2}$	Temperature in plethysmograph
		cc.	*cc.*		*° C.*
6......	October 30, 1930	147	94	1.6	29.2
	October 31, 1930	157	116	1.4	27.6
	November 3, 1930	137	95	1.4	28.9
	December 11, 1930	154	105	1.5	29.4
	March 2, 1931†	155	83	1.9	30.9
	April 15, 1931†	142	96	1.5	30.0
	April 25, 1931†	114	82	1.4	28.3
	April 28, 1931†	134	88	1.5	28.4
	May 14, 1931†	132	83	1.6	28.1
	May 22, 1931†	153	113	1.4	30.0
	May 25, 1931†	127	84	1.5	27.5
	May 29, 1931†	151	113	1.3	30.7
9......	November 12, 1930	164	131	1.3	28.1
	November 20, 1930	142	116	1.2	29.6
	November 29, 1930	125	107	1.2	26.9
	February 2, 1931	146	75	2.0	29.8
	March 4, 1931†	130	75	1.7	28.8
	April 14, 1931†	135	80	1.7	28.6
	May 18, 1931†	122	85	1.4	27.4
	May 28, 1931†	154	114	1.4	29.4
	June 2, 1931†	140	107	1.3	29.0
23......	April 1, 1931†	124	84	1.5	29.2
	April 27, 1931†	128	90	1.4	27.6
	April 29, 1931†	128	75	1.7	28.6
	May 19, 1931†	140	88	1.6	29.8
	May 20, 1931†	156	103	1.5	30.6
	May 21, 1931†	132	92	1.4	28.5
	May 26, 1931†	134	88	1.5	29.7

* Calculated in cubic centimeters per hour per square meter of skin surface at 27° C.

† Indicates that the interval between the collection of samples was two hours instead of three.

TABLE 5

The effect of age on the rate of cutaneous respiration *

Age group	Number of cases	Rate of CO_2 excretion			Rate of O_2 absorption			$\frac{CO_2}{O_2}$		
		Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
		cc.	*cc.*	*cc.*	*cc.*	*cc.*	*cc.*			
15–39	26	169	58	126	146	40	94	2.0	1.1	1.4
40–75	12	136	72	109	118	54	75	1.9	1.2	1.5

* Calculated in cubic centimeters per hour per square meter of skin surface at 27° C.

TABLE 6

*The effect of arteriosclerosis on the rate of cutaneous respiration * in subjects 40 years of age or over*

Subjects	Number of cases	Rate of CO_2 excretion			Rate of O_2 absorption			$\frac{CO_2}{O_2}$		
		Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
		cc.	cc.	cc.	cc.	cc.	cc.			
With slight or no arteriosclerosis	5	136	84	115	118	54	78	1.8	1.2	1.6
With moderate or advanced arteriosclerosis	7	124	72	104	96	48	72	1.9	1.2	1.5

* Calculated in cubic centimeters per hour per square meter of skin surface at 27° C.

that the carbon dioxide eliminated cannot originate exclusively from the metabolic processes of the skin and that diffusion of this gas from the blood through the skin is of considerable importance. In contrast to this dual source of carbon dioxide, the oxygen absorbed by the skin probably is utilized entirely in tissue oxidation, no part of it passing into the blood by diffusion through the tissues (3).

Range of cutaneous respiration in normal subjects. Although the observations of earlier investigators (1) had led us to expect a relatively wide range of normal values for carbon dioxide elimination and oxygen absorption through the skin of different individuals, we did not anticipate the extreme variations actually observed. Whether the differences are due mainly to individual variations in the extent to which the metabolic requirements of the skin are supplied by the exchange of gases between the tissues and the air or to variations in the actual metabolic rate of the skin of different subjects cannot be stated with certainty. It seems doubtful, however, that the metabolic rate of the skin is subject to much greater individual variations than the total metabolism of the body. On the other hand, it is conceivable that, as the result of individual differences in blood supply to the skin, tension of oxygen and carbon dioxide in the blood, and other factors, the amount of oxygen supplied to the skin by the blood and the amount of carbon dioxide removed may vary widely. Variations of this kind produce reciprocal changes in the rate of oxygen absorption and carbon dioxide elimination through the skin (3). We are inclined to believe, therefore, that the wide range of normal values is due in large part to individual differences in the extent to which the exchange of gases between the blood and the skin meets the needs of cutaneous metabolism, rather than to differences in the metabolic rate of the skin.

It has been suggested (1) that the relatively wide variations observed in the respiratory quotient of cutaneous respiration are due mainly to the fact that carbon dioxide diffuses through living tissues more rapidly than does oxygen, and so slight changes in the carbon dioxide tension of the cutaneous blood cause disproportionate changes in the respiratory quotient. If this hypothesis were correct, the rate of oxygen absorption through the skin should be more constant than the rate of carbon dioxide elimination, provided, of course, that the respiratory quotient of the skin itself remained constant. Inspection of the data in Tables 2 and 4 reveals that variations in the rate of oxygen absorption were as great as the variations in the rate of carbon dioxide elimination and were responsible for fluctuations in the respiratory quotient as frequently as were changes in the rate of carbon dioxide elimination. It seems, therefore, that either the extra-metabolic factors influencing the rate of oxygen absorption through the skin vary as greatly as do the factors affecting the rate of carbon dioxide elimination or that the observed fluctuations in respiratory quotient reflect actual changes in the metabolic processes of the skin. Although no final decision can be made at present, it seems doubtful that changes in the intrinsic metabolism of the skin are the responsible factor.

Variations in the effect of temperature on the rate of cutaneous respiration. The rate of cutaneous respiration increases as the temperature of the air in contact with the skin rises, but the relationship between temperature and the rate of cutaneous gas exchange varies widely in different individuals (Table 1). Because of the evidence that the oxygen absorbed by the skin is utilized entirely in tissue oxidation (3), we believe that the accelerated rate of gas-exchange accompanying increased temperature is due principally to a rise in the metabolic rate of the skin. It is probable, however, that the metabolic rate of the skin is affected by changes in temperature in a more or less equal degree in all normal subjects. The blood supply to the skin also increases with higher temperatures, and the improved circulation undoubtedly supplies part of the increased metabolic needs of the tissues. Because of differences in the sensitivity of the autonomic nervous system, the degree to which the blood supply is altered in response to changes in temperature may vary within wide limits in different individuals. Variations are therefore to be expected in the extent to which the circulating blood supplies the increased metabolic needs of the skin at higher temperatures. We believe that differences of this kind, rather than differences in the effect of temperature on the metabolic rate of the skin, are responsible for the observed variations in the effect of temperature on the rate of cutaneous respiration.

Variations in repeated measurements of the rate of cutaneous respiration in the same individual. In different individuals, variations in carbon dioxide elimination, oxygen absorption and respiratory quotient probably are due in large part to constitutional factors inherent in the subjects. The variations observed in repeated measurements on the same subjects under identical conditions of temperature and humidity (Table 2), however, are due to unrecognized changes in the experimental conditions or to physiological variations in the patients. The analytical error for the measurement of carbon dioxide excretion in our system was about $\pm$ 1.3 cc. per hour per square meter of skin surface, and for oxygen absorption about $\pm$ 2.6 cc. per hour. Even though allowance is made for this error, it is still evident that in many of the experiments summarized in Table 2, some factor or group of factors capable of producing changes in the rate of cutaneous respiration and in the respiratory quotient remained uncontrolled. In view of the evidence that fluctuations in the tension of carbon dioxide and oxygen in the blood cause changes in the rate of cutaneous respiration (3), it seems probable that physiological variations in the tension of the blood gases constitute the principal factor responsible for the differences observed in repeated measurements under identical conditions of temperature and humidity.

Effect of season on the rate of cutaneous respiration. Shaw, Messer and Weiss (1) observed a distinct tendency for the rate of carbon dioxide elimination through the skin to increase during the colder months of the year. Our studies, on the other hand, have revealed no evidence of seasonal variations in the rate of cutaneous respiration (Table 4). The experiments of Shaw, Messer and Weiss were made before the introduction of measures to control the humidity of the air within the plethysmograph, while our observations were made with the air in the system at the saturation point. This difference in technique may account for the discrepancy in results.

Effect of age on the rate of cutaneous respiration. The tendency for subjects above the age of 40 years to have a lower rate of cutaneous respiration than younger individuals (Tables 1 and 5) is of considerable interest. The fact that the diminution in rate tended to be more marked in those individuals having moderate or advanced generalized arteriosclerosis than in those having slight or no evidence of arteriosclerosis (Table 6) suggests that the decrease is related to involutionary changes in the skin.

Certain experiments of Shaw and Messer (3) indicate that diminished blood supply to the skin is attended by an increased rate of cutaneous gas exchange, provided that the metabolic rate of the skin remains unchanged. In other words, a decrease in the degree to which the circulating blood supplies the metabolic needs of the skin is compensated for by an increase in the extent to which those needs are met by direct exchange of carbon dioxide and oxygen through the skin. In view of this consideration, diminished blood supply to the skin cannot be responsible for the observed reduction in the rate of cutaneous respiration in subjects above the age of 40 years. On the other hand, the evidence that the oxygen absorbed by the skin is utilized entirely in tissue oxidation (3), suggests that the reduced rate of cutaneous gas exchange is due to an actual decrease in the metabolic rate of the skin.

Relation between the rate of respiratory exchange through the lungs and the rate of cutaneous respiration. In our subjects, the cutaneous exchange of carbon dioxide and oxygen amounted to a much larger percentage of pulmonary exchange than observed by earlier investigators. Aubert (4) estimated that one-half of one per cent of the expired carbon dioxide was eliminated through the skin. The data presented by Zuelzer (5) indicated that the average amount of oxygen absorbed by the skin was one per cent of the amount absorbed through the lungs. Because of errors inherent in the methods utilized by these observers, the results obtained are of doubtful value. Shaw, Messer and Weiss (1) calculated that in their two subjects the carbon dioxide eliminated through the skin amounted to one per cent of that given off through the lungs. In our observations on 17 subjects, the average cutaneous absorption of oxygen amounted to 1.9 per cent of pulmonary absorption, and the cutaneous elimination of carbon dioxide amounted to 2.7 per cent of pulmonary elimination. In view of the fact that cutaneous respiratory exchange results in part from the metabolism of the skin and in part from the diffusion of carbon dioxide through the skin, it is not surprising that, in individual subjects, no exact relationship was observed between the rate of cutaneous respiration and the rate of carbon dioxide elimination and oxygen absorption through the lungs.

SUMMARY

1. Repeated measurements were made of the rate of carbon dioxide elimination and oxygen absorption through the skin in 38 normal subjects.

2. The rate of carbon dioxide elimination per hour per square meter of skin surface at 27° C. varied in different individuals from 58 cc. to 169 cc. with an average value of 120 cc.

3. The rate of oxygen absorption per hour per square meter of skin surface at 27° C. varied in different individuals from 40 cc. to 146 cc. with an average value of 88 cc.

4. The respiratory quotient of cutaneous gas exchange at 27° C. averaged 1.4 and varied between 1.1 and 2.0.

5. With each degree rise in the temperature of the air in contact with the skin, an average increase of 8 cc. per hour per square meter of skin surface was observed in both carbon dioxide elimination and oxygen absorption. The accelerated rate of gas exchange through the skin at higher temperatures probably is due principally to an increased rate of cutaneous metabolism.

6. No relationship was observed between the rate of cutaneous respiration and the sex of the subjects or the season of the year.

7. The rate of carbon dioxide elimination and oxygen absorption through the skin tended to be lower in subjects above the age of 40 years than in those below that age. The diminished rate of cutaneous respiration in subjects above the age of 40 years probably is due to a decreased metabolic rate of the skin.

8. In 17 subjects, the average amount of oxygen absorbed through the skin was 1.9 per cent of that absorbed through the lungs, and the average amount of carbon dioxide excreted through the skin was 2.7 per cent of that excreted through the lungs. In individual subjects no exact relationship was observed between the rate of respiratory exchange through the lungs and the rate of cutaneous respiration.

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