THE BLOOD SUPPLY OF VARIOUS SKIN AREAS AS ESTIMATED BY THE PHOTOELECTRIC PLETHYSMOGRAPH[1]

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Information on the skin circulation has been supplied in the past by observations of skin color and temperature, by inspection of limited skin areas, by limited plethysmography, by measurements of skin conductivity, by oscillometry of ear arteries. The application of the mechanical plethysmograph has been necessarily limited to such areas as the ears, fingers and toes in which the circulatory changes are not confused by the participation of vascular beds in deeper tissues such as the muscles. It is possible that the ears, fingers and toes show vascular reactions unlike those in other skin areas. Such differences become increasingly probable when one considers the distribution of arterio-venous anastomosis in the skin.

The development of the photoelectric plethysmograph (1) offered the opportunity to apply the principle of plethysmography to the study of the circulation in various skin areas hitherto unexplored in plethysmographic studies. This paper details data which have been thus obtained on the skin circulation in healthy adult male subjects at rest. The data represent an attempt at estimating the arterial blood supply of various skin areas. They are, therefore, related to problems of heat dissipation by the skin, to the significance of skin temperature measurements, and to the study of vascular reactivity in various skin areas.

Method. Advantage is taken of the fact that the absorption of light by a transilluminated tissue varies with its blood content, to detect vascular changes with the photoelectric cell (fig. 1). One uses as an illumination source, a pencil flashlight bulb carried on a metal plunger in the metal sleeve attached to the photocell housing. The open end of the sleeve is brought into light contact with the skin so that light reflected from the skin surface passes back into the sleeve while light entering the skin scatters and so transilluminates the skin. The resulting variations

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in the photoelectric currents are recorded on the electrocardiograph after suitable amplication with a simple 3-stage amplifier (employing the 112-A tube). It is to be noted that only light which has passed through the skin reaches the photocell. This point is important as movements of the skin surface produce exaggerated effects on the photocell if light reflected from the skin surface reaches the cell. (One may take advantage of this fact to record the skin pulsations produced by the larger arteries. In this case, the plethysmograph is placed about 1 cm. above the skin surface so that only part of the skin surface under the photocell is brilliantly illuminated. The size of the illuminated area under the photocell will pulsate with the arterial pulse thus effecting corresponding pulsatile variations in the photocell current.) The intensity of the light reflected back from the skin is also a function of the blood content. This has apparently

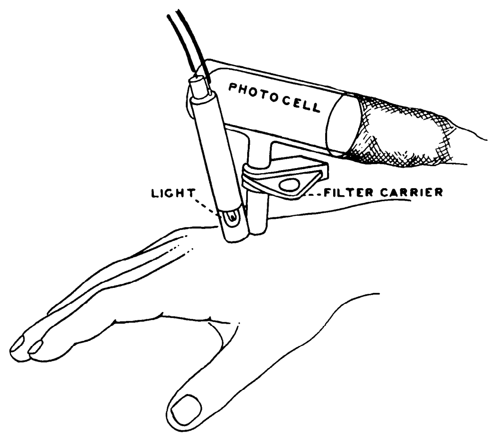

Fig. 1. The photoelectric plethysmograph in position over the skin of the hand

been used by Turner (2). The plethysmograph is carried by rack and pinion on a heavy stand for exploration of the skin of the arm, leg, hand and foot. In applying the plethysmograph to the skin of the face and forehead, it is necessary to mount it on a counter-weighted head strap due to movements of the head with the heart beat and with respiration. Adequate flexibility in alignment is provided by ball and socket joints. This arrangement is sufficiently comfortable for observation periods up to an hour in length. Although this form of the plethysmograph may be used on the ear and the data on the ear in table 4 were so obtained, another arrangement is more easily applied and is less subject to errors from movement of plethysmograph with respect to skin. In this alternate arrangement the light source is placed on one side of the ear and the photoelectric cell on the other side. The light affecting the photocell passes through the thickness of the ear. The instrument is here suspended as before from a head strap.

Quantitation of the plethysmogram is provided for in terms of arbitrary units by recording on the plethysmogram (fig. 2) the deflection resulting from inserting a thin sheet of glass between the photocell and the skin surface. The glass sheet (called filter in the figure and hereafter) is mounted in a swinging plate attached to the photocell housing. The filter is in position to absorb light only when calibration is desired. It is otherwise swung out of line with the light path during the actual recording of the plethysmogram. The variations in the latter due to the volume pulse or to slower and larger changes in blood content are compared with the deflection resulting from the insertion of the filter and calculated in filter units by dividing the excursion in the plethysmogram due to variation in blood content by the deflection due to insertion of the filter. Thus, in figure 2, the filter deflection is 7 mm and the amplitude of the volume pulse is 5 to 6 mm. or equivalent to 0.8 filter unit.

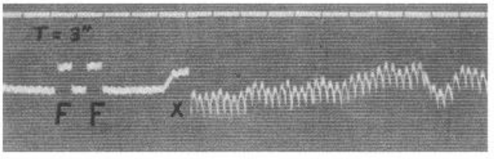

Fig. 2. Photoelectric plethysmogram of forehead illustrating method of quantitating the plethysmogram in arbitrary units with the aid of a filter, inserted at *F*. String shunt resistance increased at *X*.

The problem of the actual blood equivalent of the filter is a complex one. The sources of error in photoelectric plethysmography discussed below bear on the question. An empirical approach is provided by the data obtained by Turner, Burch and Sodeman (2) with their highly sensitive mechanical plethysmograph on the finger tip. From their table 1, one obtains an average volume pulse in the finger tip at heart level of 2.8 cu. mm. or approximately 0.06 per cent of the soft tissue volume. Under similar conditions of room temperature and humidity, the average amplitude of the photoelectrically recorded volume pulse in the finger tip at heart level is 1.85 filter unit (table 4), in the case of male adults in the sitting position, comfortably clothed, after twenty minutes of rest. Since the volume pulse as recorded photoelectrically and mechanically in the two groups of data have been obtained from analogous portions of the fingers, one may calculate that one filter unit is, therefore, approximately equivalent ot 0.033 cc. blood. Absolute accuracy cannot be claimed for this value but it serves for comparative purposes. It is important to note that the volume pulse as recorded from the entire finger by enclosing it in a mechanical plethysmograph cannot be considered as equivalent to that recorded photoelectrically from the finger pad, after making due allowances for differences in volume of tissue involved, since the amplitude of the volume pulse is maximal in the pad of the finger tip and is very much less on the dorsum of the finger.

Sources of error. 1. *Movements.* The most important source of error and the one most difficult to control is movement of the skin with respect to the plethysmograph. Periodic movements due to the respirations and due to the ballistic effects of the heart beat on the entire body are largely eliminated from the arms and legs by flexion. These effects are so large in the case of the trunk that it has not been possible to apply the plethysmograph here. They are largely eliminated from the head in most subjects by mounting the plethysmograph on a head strap. Movements of the underlying muscles shift the position of the skin with respect to the plethysmograph. These effects may vary from fine tremors in the recorded pulse wave to gross distortion of the plethysmogram. Fortunately, the effects are quite characteristic and readily recognized so that data so distorted may be eliminated from consideration.

2. *The presence of a large artery beneath the plethysmograph* results in the recording of the pulse in this vessel. Neither the amplitude nor the form of the recorded wave is then a criterion of the arterial circulation in the skin. The plethysmogram will then fail to distinguish between large artery and skin artery reactions.

3. *Character of contact of the plethysmograph with the skin.* If the plethysmograph rests too firmly against the skin, progressive stasis in the skin vessels results showing itself in a corresponding quite uniform drift in the record. Fairly heavy pressure is required to produce noticeable stasis. Light pressure does not seem to interfere with the recording of vascular reactions nor does it produce recordable stasis. If the plethysmograph comes out of contact with the skin, light reflected from the skin reaches the photocell. The effect mimics vasoconstriction in the skin and exaggerates the influence of vasoconstriction occurring in deeper tissues, causing the skin to drop away from the plethysmograph. The amplitude of the recorded volume pulse is also changed considerably. It is, therefore, preferable to use the plethysmograph over areas in which the bones lie near the surface. Considerable experience with the technique provides confidence in one's ability to repeatedly duplicate recording conditions by repeated application of the plethysmograph to the same skin area (table 1). The range of variation in the amplitude of the volume pulse in the different trials is no greater than what may be observed during continuous recording without disturbance in the position of the plethysmograph. The values for the finger tip are lower than those reported in table 4. The differences are probably due to difference in room climate.

The constrictor effect of cold is also shown illustrating the ability of the plethysmograph to reveal such changes.

4. *The size of the vascular area under observation.* The size of the vascular area vertical to the plane of the incident light involved in the plethysmogram may include not only the areas directly beneath the photocell and the light source but possibly also a variable amount of adjoining tissue. The extent of the latter is not necessarily determinable by the extent of the visibly luminous area since plethysmography is possible also with invisible infra-red wave lengths which show greater penetration. *However,* the most intense illumination is of tissues directly beneath the light and it, therefore, follows that the effects of variations in the blood content

TABLE 1

Showing the degree of uniformity in the recorded amplitude of the volume pulse on repeated applications of the plethysmograph to the same skin area

Room temperature: 74°F. Relative humidity: 34

SKIN AREA	STRING EXCURSION TO FILTER	STRING EXCURSION TO PULSE	PULSE AMPLITUDE CALCULATED IN FILTER EQUIVALENTS
	mm.	*mm.*	
Side of nose	10.0	9.0	1.0
	9.5	9.0	0.95
	11.0	10.5	0.95
	10.5	8.0	0.76
	9.0	9.0	1.0
Finger tip	10.5	14.0	1.33
	9.0	10.5	1.17
	8.0	12.0	1.50
	8.0	11.0	1.38
Same finger tip after immersion of hand in cold water for 2 minutes	10.0	3.0	0.30
3 minutes later	13.0	7.0	0.54

will be maximal here, progressively decreasing as the light intensity diminishes, the latter decreasing in geometrical progression as the thickness of the absorbing medium increases in arithmetical progression. It, therefore, seems improbable that significant error will appear in the plethysmogram due to illumination of vascular areas beyond those immediately beneath the light and photocell. In order for light to reach the photocell from these more distant areas, it must again pass back through the tissues. The amount of light so reaching the photocell is probably very small and variations in it with the distant vasculature must indeed be small compared with those resulting from vascular reactions beneath the photocell and light. These statements are supported by the following observations on the skin of the forehead: when light from a source identical to that of the plethysmograph was directed on the skin, it could be detected by the plethysmograph at a horizontal distance of 40 mm. providing the amplifier was operated at maximum sensitivity and providing the skin beneath the plethysmograph was not illuminated except by the distance light source. However, if the plethysmograph was operated at its usual sensitivity and with the skin beneath brilliantly transilluminated in the usual manner, the distant light could not be detected unless moved to within 10 mm. of the plethysmograph. Even so, the resulting deflection was less than that due to the pulse. *Its presence at that distance did not affect the amplitude of the recorded pulse.* It, therefore, seems fairly safe to assume that the areas significantly involved in the plethysmograms are only the two areas beneath the light and the photocell.

5. *The depth of penetration of the light.* The problem of the depth of tissue involved in the plethysmogram is a more stubborn one and one which is important to accepting the records as plethysmograms of the skin circulation only. The results of Hardy and Muschenheim (3) on the transmission of light by skin suggest that the distance penetrated is small and that the plethysmograph does not record the circulation in the deeper tissues. The possibility of the latter directly affecting the plethysmogram is obviously eliminated in the case of skin areas over bone. Since the plethysmograph does not record total light intensity but simply fractional variations in the light reaching it (amplification and, therefore, sensitivity being altered with variation in absolute light intensity), it seems probable that essentially the same depth of tissue is involved in various skin areas, provided plethysmograph sensitivity is adjusted to light absorption. Thus, if absorption is greater in one area than another, increased sensitivity of the plethysmograph would compensate for the decreased intensity of the light reaching it, tending to thus maintain the effective depth constant. Conversely, increased intensity of illumination with corresponding greater penetration would increase the effective depth if the plethysmograph's sensitivity were not proportionally decreased. That the effect is to maintain the effective depth constant is indicated in the results described below giving the same amplitude of the volume pulse (in filter units) when employing two light sources differing greatly in intensity. The fact that the amplitude of the volume pulse (calculated in filter units) is within the normal range for finger pads of normal subjects regardless of whether the hands are calloused or whether heavily pigmented as in the case of negroes is further evidence that the effective depth involved in the plethysmogram is essentially the same. The argument would fail quantitatively, however, when variation in absorption occurred without corresponding compensatory changes in plethysmograph sensitivity. That the error cannot be large is indicated by the agreement between the mechanical and photoelectric plethysmograms simultaneously recorded.

6. *Variations in intensity and spectrum of the illumination.* The spectral distribution of energy and the intensity of the light will vary slightly in the case of fresh incandescent bulbs operated similarly and slightly below their rated voltage. Small variations in these factors are relatively unimportant to the plethysmograph since one is not concerned with the absolute intensity of the light reaching the photocell providing it is sufficient to operate the plethysmograph. The amount of light absorbed in the observed area due to its blood content and due to variations in the latter will be some fraction (undetermined) of the total light penetrating the tissues and will bear some approximately constant relation to that absorbed by the filter in the plethysmograph. It is for this reason that fair success was experienced in attempting to arrive at the blood equivalent of the filter in the case of the finger plethysmograph (1). These statements are further supported by the following experiments on the finger tips: the pulse amplitude was calculated in arbitrary filter equivalents from two successive records in which the same filter was used but in which were employed two different bulbs (one an ophthalmoscope bulb, the other a pencil flash-light bulb) obviously differing greatly in the intensity of the emitted light. The filter equivalent of the pulse amplitude was the same in each record. However, this is no longer true if the spectrum of the light changes considerably as from the "white" light of the filament operated near its rated voltage to the "yellow" light resulting from falling battery voltage. It is, therefore, preferable to operate the bulb on a storage battery and to replace the bulbs quite frequently.

Experimental illustration of the validity of photoelectric plethysmograms of the skin circulation. Simultaneous plethysmograms, photoelectrically and mechanically recorded of the fingers, are exhibited in figure 3. The mechanical plethysmogram was obtained from one entire finger, the photoelectric plethysmogram from the pad of the tip of another finger. The figure illustrates the spontaneous activity of the finger vessels. The complete agreement between the two plethysmograms is obvious. Similarly perfect agreement was exhibited in the recorded responses to painful and psychic stimuli, cold, amyl nitrite, voluntary apnea and the Valsalva experiment. Such data did not permit doubt of the ability of the photoelectric plethysmograph to follow and faithfully record the vascular changes in the skin in procedures such as these giving rise to rather short-lived vascular reactions.

It seemed desirable, however, to explore the validity of more prolonged records in which the effects of reduction of oxy-hemoglobin in the skin vessels on the plethysmogram may be estimated. Matthes (4), Kramer (5), and also Gross (6) have followed photoelectrically the reduction of oxy-hemoglobin in the blood in vitro and in vivo. It is obvious from their experiments that since reduced hemoglobin has a greater opacity than oxy-hemoglobin, increasing amounts of reduced hemoglobin in the skin vessels may mimic dilatation. It is thus possible that this source of error may at times invalidate the photoelectric plethysmogram.

Evaluation of the magnitude of the error was attempted through the performance of two types of experiment in which simultaneous photoelectric and mechanical plethysmograms of the fingers were recorded:

1, stasis prolonged to obvious cyanosis;

2, rebreathing room air until signs of marked anoxia, cyanosis, dizziness, respiratory stimulation, etc.

In the stasis experiments, the two plethysmograms tended to separate from each other. A possibly important factor contributing to this separation is the venous drainage of blood out of the finger into the hand

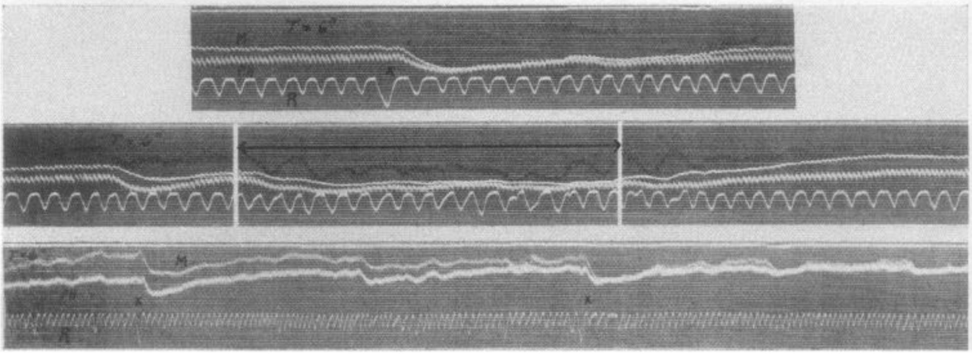

Fig. 3. Simultaneous photoelectric (*PH*) plethysmogram of pad of one finger and mechanical (*M*) plethysmogram of neighbor finger.

Upper record: constriction following deep inspiration at *X*.

Lower record: same, and in addition "spontaneous waves."

Middle record: immersion of opposite hand in ice-water between signals. Anticipatory constriction.

and arm veins which apparently form a more capacious reservoir (7) than those in the finger. This effect may be less prominent in the smaller veins of the finger tip. The evidence for the influence of accumulating reduced hemoglobin on the plethysmogram is therefore not as conclusive as one would have expected.

The rebreathing experiments presented evidence of the effects of reduction of hemoglobin only when the skin cyanosis became quite marked. Even so the disagreement between the mechanical and photoelectric plethysmograms was relatively slight. Although these experiments suggest the advisability of limiting the application of the photoelectric plethysmograph to those instances in which the ratio of reduced to oxygenated hemoglobin in the skin vessels is not greatly altered, they do not diminish confidence in the validity of the photoelectric plethysmogram in the study of vascular reactions of the skin where this requirement is satisfied.

The volume pulse of the skin as an indicator of the state of the skin circulation (at rest). Wave form: As a rule, the volume pulse recorded from various skin areas, with the exception of the digits, shows a well-rounded wave in which the dicrotic wave is only slightly apparent and is placed high (usually on top) on the main wave. In the case of the digits, the wave has a triangular form with a well pronounced dicrotic wave on the catacrotic limb. In fact, the volume pulse is here indistinguishable in form from the peripheral arterial pulse, suggesting that the wave form depends upon the accidental inclusion or omission of sufficiently large arteries in the plethysmographic field to impress the arterial pulse wave form on the recorded volume pulse. Constriction in the finger tip changes the wave to a rounded form so that it resembles that in other areas. This type of wave may be due, therefore, either to absence of larger arteries or to constriction in the area observed. It is conceivable that the wave form may bear on the conclusions drawn below concerning the relative richness of the blood supply in the various skin areas studied.

Amplitude of the volume pulse as a measure of the blood supply of the skin. The amplitude of the volume pulse in a skin area will depend on the relation between arterial inflow and venous outflow in that area. If circulatory dynamics are normal in the observed area, it is probable that capillary and venous pulsation will not be detectable. However, the possibility of such a contribution to the volume pulse amplitude cannot be eliminated from consideration. This has not been studied at present with the photoelectric technique. Nevertheless, the amplitude of the volume pulse will be most dependent on the pulsatile excursions in arterial flow into the area and so will be a measure of the arterial supply. This is illustrated in table 1 in the decreased flow in the finger resulting from immersion in cold water. The argument finds further experimental support in data obtained under conditions in which other indirect evidence supports the photoelectric criteria of decreased arterial supply in the observed skin areas. Thus, in table 2, the known decrease in the arterial supply of the fingers in a case of Raynaud's disease is well indicated by the photoelectric criterion. The demonstration is given increased emphasis by the striking contrast in the amplitudes of the volume pulses of the finger tips recorded from this patient and from a normal subject just a few minutes previously. The possibility that a left cervical sympathectomy resulted in a slight dilatation in the left side of the face is also suggested by the data in table 2.

One might expect that a generalized erythema due to sunshine would offer a further convenient test of the argument. Table 3 presents such data. Although the amplitudes of the volume pulses exceed the summer averages for the corresponding skin areas, they are not beyond the upper limits of the normal range for summer. Since the observations were made on a warm day, one is uncertain whether the increased volume pulses are due to the erythema or to the warm weather. The increases in the volume pulses do not appear proportional to the erythema suggesting that the skin arteries participate less in the reaction than do the capillaries and venules.

TABLE 2

Influence of Raynaud's disease and of left cervical sympathectomy on the photoelectrically recorded volume pulse of several skin areas (summer values)

Compare with table 4

SKIN AREA	PULSE AMPLITUDE (FILTER UNITS)	SKIN AREA	PULSE AMPLITUDE (FILTER UNITS)
Finger pad (normal subject)	5.2–6.5	Forearm	Indeterminate
Finger pad—2nd (Raynaud's)	0.23	Forehead (right)	0.60
Finger pad—3rd	Indeterminate	Forehead (left)	1.0
Finger pad—4th	0.58–0.8	Nose (right)	0.70
Finger pad—5th	0.10	Nose (left)	1.0
Thenar eminence	0.58–0.75	Ear lobe (right)	0.33
Hypothenar eminence	0.36–0.55	Ear lobe (left)	0.34
Dorsum hand	0.41		

TABLE 3

Amplitude of volume pulse in several skin areas in a case of erythema due to sunshine

Normal subject. Temperature: 92°F. Relative humidity: 43. Compare with table 4.

SKIN AREA	PULSE AMPLITUDE (FILTER UNITS)	SKIN AREA	PULSE AMPLITUDE (FILTER UNITS)
Forehead	2.0	Finger pad	4.6–5.2
Nose	1.68	Dorsum finger	0.75
Ear lobe	3.0	Dorsum hand	0.6
Ear (upper part)	1.0–1.4	Forearm	0.24
Cheek	1.4–1.8	Toe pad	2.5–2.8

The argument that the amplitude of the volume pulse is a criterion of the blood supply of the skin has been applied to a comparison of the richness of the blood supply of various skin areas (table 4). The data have been obtained on healthy male adults in the sitting position, comfortably clothed, after twenty minutes of rest. The values on the arms, hands and fingers were obtained with these areas at heart level; those for the leg and foot with the leg comfortably raised to a level slightly below heart level. This is an important provision as the volume pulse is significantly influenced by the vertical distance of the part above or below the heart (2),

TABLE 4

Amplitude of volume pulse (in filter units) in various skin areas of healthy male adults

SKIN AREA	SEASON	SUBJECTS	OBSERVATIONS	RANGE	AVERAGE
Finger pad	W	3	5	0.96–2.4	1.76
	Sp.	3	5	1.0 –2.8	1.85
	Su.	11	17	2.1 –6.5	3.4
Forehead	W	8	17	0.43–1.63	0.94
	Sp.	7	7	0.43–1.54	1.00
	Su.	7	9	0.67–2.0	1.00
Forearm	W	4	11	0.15–0.48	0.31
	Sp.	6	7	0.0 –0.34	0.17
	Su.	6	8	0.0 –0.59	0.30
Ear lobe	Sp.	6	6	0.53–1.43	0.97
	Su.	6	9	0.75–3.3	1.80
Toe pad	Sp.	5	6	0.30–1.2	0.63
	Su.	5	8	0.28–2.5	1.23
Nose (side)	Sp.	6	6	0.67–1.43	1.07
	Su.	6	8	0.70–1.75	1.17
Cheek	Sp.	7	7	0.31–1.07	0.68
	Su.	3	3	1.1 –1.3	1.20
Lip	Sp.	4	4	0.83–1.80	1.16
Thenar eminence	Sp.	5	5	0.32–1.4	0.90
Hypothenar eminence	Sp.	4	4	0.46–2.26	1.04
Palm (hand)	Sp.	3	3	0.38–1.71	0.90
Dorsum finger	Sp.	8	8	0.25–0.92	0.54
	Su.	2	2	0.50–0.90	0.70
Dorsum hand	Sp.	6	6	0.0 –0.68	0.37
	Su.	6	8	0.20–0.70	0.47
Dorsum foot	Sp.	5	5	0.0 –0.45	0.11
	Su.	3	4	0.0 –0.33	0.20
Knee	Sp.	6	6	0.0 –0.46	0.20
Tibia	Sp.	6	6	0.0 –0.21	0.04
Dorsum toe	Sp.	5	7	0.0 –0.38	0.15

Spring (Sp) and winter (W) temperatures in room 75–80°F; relative humidity 30. Summer (Su) temperatures in room 82–93°F; relative humidity 38–47.

a fact which our own experience confirms. The data have been grouped into three divisions according to the season of the year. However, the room climate was essentially the same during the winter and spring observations so that the separation of these is probably not necessary as indicated by the essential identity of the winter and spring averages for the finger pad, forehead and forearm areas. The data indicate that a rich arterial blood supply is limited to the skin of the palmar surface of the hand and fingers, the plantar surface of the toes, the forehead, face and ear. The dorsal aspects of the hands and feet and the plantar surface of the feet have a much poorer arterial supply. The arterial supply to the skin of the arm and leg is so poor that the volume pulse in these areas is not recorded satisfactorily. In many instances, the amplitude of the volume pulse is indeterminate.

One might expect that vasomotor reactions would be more pronounced in the skin areas with the richer arterial supply. Grant and Pearson (7) have recently shown striking differences in the vascular reactions of the forearm and of the hand. Others (8) have suggested greater vascular reactivity in the hand than in the foot. However, our own experience suggests that such differences in vascular reactivity are not necessarily dependent upon the richness of the arterial supply. Thus, in table 4, we observe a surprising seasonal constancy in the volume pulse of the forehead, nose, forearm and dorsum of the hand and foot in contrast to the dilatation in warm weather in the finger pad, toe pad and ear. Similarly observations on the vascular responses of the forehead, ear and finger to the cold pressor test (9) indicate the lability of the arteries of the finger in contrast to the absence of significant reactions in the forehead and ear.

These data support the suggestion of Grant and Pearson (7) that the dissipation of heat from the hand and forearm is greatly affected by digital blood flow and that the venous flow in the skin of the hand and forearm is derived importantly from the digits and the muscles below the skin. They are in further agreement with the constancy of forehead skin temperature, a fact well-known to clinicians and recently commented on by DuBois (10).

SUMMARY

1. Advantage may be taken of the fact that the absorption of light by a transilluminated tissue varies with its blood content, to detect vascular changes with the photoelectric cell. The application of this principle of photoelectric plethysmography to the study of the skin circulation is described. The sources of error involved in the quantitation of the skin plethysmogram are discussed. They bear on the problem of the blood equivalent and on the qualitative accuracy of the plethysmogram. They are:

a. Movement of the skin with respect to the plethysmograph.

b. Influence of large artery in the immediate neighborhood of the area being observed.

c. Character of contact of the plethysmograph with the skin.
d. Size and depth of the vascular area involved in the plethysmogram.
e. Variations in the intensity and spectrum of the illumination.
f. Influence of reduced hemoglobin—oxygenated hemoglobin ratios on the skin opacity.

2. The essential validity of the photoelectric plethysmogram is demonstrated in simultaneous plethysmograms, photoelectrically and mechanically recorded, of the fingers, in instances where the vascular responses to some common procedures were followed.

3. The argument is advanced and supported by suitable data that under resting conditions, with normal circulatory dynamics, the volume pulse of the skin area is a measure of the richness of the arterial blood supply of that area.

The skin areas thus studied arrange themselves in descending order of the richness of their arterial supply as follows: finger pad, ear lobe, toe pad, palm of hand, skin of forehead and face, dorsum of finger, of hand and of foot, forearm, knee and tibia. Other areas could not be estimated.

4. The effect of climate on the arterial blood supply of these areas is also indicated.

REFERENCES

(1) Hertzman, A. B. Proc. Soc. Exper. Biol. and Med. **37**: 290, 529, 1937.
Hertzman, A. B. and C. R. Spealman. This Journal **119**: 334, 1937.
(2) Quoted in: Turner, R. H., G. E. Burch and W. A. Sodeman. J. Clin. Invest. **16**: 789, 1937.
(3) Hardy, J. D. and C. Muschenheim. J. Clin. Invest. **15**: 1, 1936.
(4) Matthes, K. Arch. f. Exper. Path. u. Pharmakol. **179**: 698, 1935.
(5) Kramer, K. Ztschr. f. Biol. **96**: 61, 1935.
(6) Gross, F. Ztschr. f. d. ges. Exper. Med. **102**: 766, 1938.
(7) Grant, R. T. and R. S. B. Pearson. Clin. Sci. **3**: 119, 1938.
(8) Allen, E. V. and G. R. Crisler. J. Clin. Invest. **16**: 649, 1937.
(9) Hertzman, A. B. Proc. Soc. Exper. Biol. and Med. **38**: 1938. In press.
(10) DuBois, E. F. The mechanism of heat loss and temperature regulation, p. 75. Lane Medical Lectures 1937. Stanford University Press.