AN OBJECTIVE NO-CONTACT METHOD OF STUDYING THE COLOR OF THE HUMAN SKIN WITH A PHOTOELECTRIC COLORIMETER

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A method of determining the color of the human skin based on the use of a no-contact photoelectric colorimeter specially designed for this purpose is described. The mean values of the color indices for the skin of the anterior and posterior surfaces of the forearm of 45 normal men and 35 normal women of the European race are given.

KEY WORDS: skin; photoelectric colorimeter.

The study of differences in the color of the human skin based on race, age, sex, and regional factors, as well as changes in skin color produced by various external agents and physiological and, in particular, pathological states, is of considerable importance at the present time. However, these problems have received little study because of the imperfections of existing methods of recording skin color. Subjective, qualitative methods are based on visual comparison with standard colors [7, 9, 10]; more precise, objective methods are based on the use of spectrophotometers [1, 3, 6] and photoelectric colorimeters [4, 5, 8]; all known objective methods require contact between the measuring instruments and the skin surface and this itself causes changes in skin color. In the case of disease of the skin, these methods cannot be used.

The authors have devised a method of no-contact determination of skin color by means of the FM-104M photoelectric colorimeter, specially designed for this purpose; by its use the color characteristics of parts of the body can be measured with a high degree of accuracy during their illumination from a standard colorimetric C source (6,500°K), the emission spectrum of which corresponds approximately to that of daylight.

The apparatus uses a photoelectric method of color measurement based on a radiation receiver whose spectral sensitivity is reduced by means of special correcting filters to the summation functions $x_H(\lambda)$, $y(\lambda)$, and $z(\lambda)$, characterizing the color properties of the eye of an average standard observer.

The measuring system of the instrument is such that either the photocurrents I_X, I_Y, and I_Z, proportional to the color coordinates, or their ratios $\alpha = I_X/I_Y$ and $\beta = I_Z/I_Y$, can be recorded.

During measurement of the ratios between the photocurrents α and β the magnitude of the photocurrent I_Y is reduced to a constant equal to a conventional unit; this is done by making a smooth change in the electrical sensitivity of the instrument. In this case the photocurrents I_X and I_Z are numerically equal to the values of α and β.

The switch from the system of coordinates α, β to the international color system x, y is done either by calculation or with the aid of a special nomogram, in which a grid of constant values of x, y is plotted in coordinates α, β, so that all calculations can be dispensed with.

Since the function $\bar{y}(\lambda)$ coincides with the function of visibility of the eye $V(\lambda)$, the instrument can be used to measure the brightness B of radiation falling into it. The value of B, together with the co-

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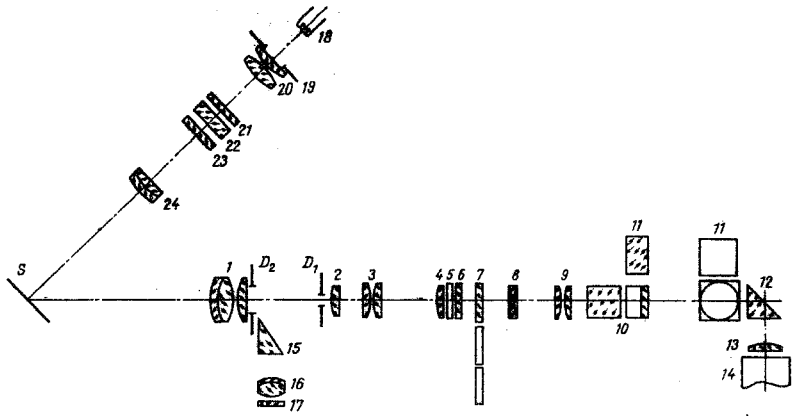

Fig. 1. Optical system of instrument (explanation in text).

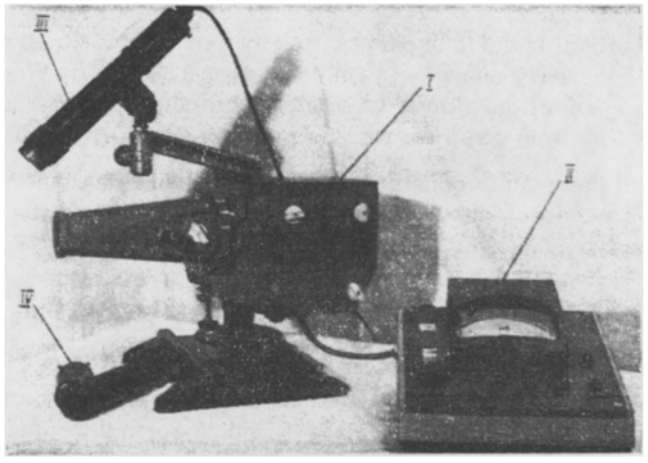

Fig. 2. General view of the FM-104M colorimeter (explanation in text).

TABLE 1. Mean Values of Color Indices for Skin of Anterior and Posterior Surfaces of Forearm of 45 Normal Men and 35 Normal Women

Color index	Men		Women	
	anterior surface	posterior surface	anterior surface	posterior surface
x	0,360	0,376	0,360	0,371
y	0,353	0,362	0,352	0,356
λ (nm)	583	584	584	585
p (%)	29	35	27	32
ρ (%)	34,5	29,5	38,8	36,0

ordinates α, β, characterize the color of the measured object completely.

The optical system of the colorimeter is shown in Fig. 1. It consists of the optical system of the colorimetric attachment (1-17), in which a modified system of the mass-produced FPI photometer is used, and the optical system of the source of light (18-24).

The objective (1) with aperture diaphragm (D_2) gives an image of the object to be measured (S) in the plane of the interchangeable field diaphragms (D_1). The system of lenses (2, 3, 4, 8, 9, 13) and the prism (12) form an image of the entrance aperture of the instrument on the cathode of a photoelectric cell (14). During the measurements, correcting filters (7) are introduced one by one into the beam of light. Neutral reducers (5, 6, 10, 11) are used to broaden the limits of measurement.

Interchangeable field diaphragms (D_1) are used to pick out circles 2.5, 6.5, and 13 mm in diameter on the area of skin to be measured at a distance of 150 mm from the edge of the instrument tube to the measured area. The operator controls the direction of the instrument by means of a viewfinder (15, 16, 17), in which a clear image of the object to be measured can be seen with a black spot corresponding to the size of the area to be measured.

The optical system of the source of light provides a uniformly illuminated spot 30 mm in diameter in the plane of the object to be measured. The light source (18) is projected by a condenser (20) into the

plane of the objective (24) which, in turn, projects the image of the iris diaphragm (19) on to the surface of the object. Protection against the emission of heat from the source is provided by a filter (21). The filter (22) also is introduced into the beam of light for spectral correction of the emission from the incandescent lamp under the colorimetric source C. The filter (23) is introduced during color graduation of the instrument; in that case, a white disk made of opalescent MS-20 glass is placed in the plane (S). The color of the graduating filter (23) corresponds to the mean color value of human skin.

The electrical circuit of the apparatus provides the necessary amplification of the signal from the photoelectric cell, a smooth change in the electrical sensitivity of the instrument, and a stabilized electric power supply to the photoelectric cell and amplifiers. The coordinates of color and brightness are read on a pointer-type indicator.

A general view of the instrument is given in Fig. 2. In its construction the colorimeter consists basically of the regular FPI photometer manufactured by the Zagorsk Optical-Mechanical Factory. This consists of three principal units: the colorimetric attachment (I), the recording and power unit (II), and the illuminating unit (III). During graduation, the graduating attachment (IV) with the white disk is placed over the source of light.

For convenience in investigating various parts of the human body the instrument can be mounted on a universal stand, enabling the necessary changes in its position to be made. After the instrument and source of light have been aimed at the part of the skin to be studied, the coordinates α and β and the value of B are measured in succession. The time required for one measurement is 1-2 min.

Subsequent processing of the results consists of determination of the color coordinates x and y and the reflection coefficient ρ. The coordinates of color x and y can, if desired, be converted by standard graphs [2] into the more demonstrative system of λ (color tone) and p (purity of color).

The absolute error of measurement of the color coordinates on the instrument described does not exceed 0.006 for α and β; the relative error of measurement of brightness is $\pm 4\%$. Sensitivity for α and β is 0.002; the reproducibility of the measurements for α and β is not below 0.003.

By means of the instrument described, the color indices of the skin of the anterior and posterior surfaces of the forearm were measured on 45 normal men and 35 normal women. The mean values of the coordinates of color x and y, the reflection coefficient ρ, and the coordinates λ and p thus obtained are given in Table 1.

LITERATURE CITED

1. A. D. Vadkovskaya and Kh. M. Freidin, Byull. Éksperim. Biol. i Med., No. 3, 55 (1945).
2. M. M. Gurevich, Color and Its Measurement [in Russian], Moscow–Leningrad (1950), p. 78.
3. A. A. Il'ina, Fiziol. Zh. SSSR, No. 3, 338 (1949).
4. G. B. Buck and H. C. Froelich, Illuminat. Eng., 53, 27 (1948).
5. M. G. De Kleine, Plast. Reconst. Surg., 15, 176 (1955).
6. E. A. Edwards and S. Q. Duntley, Am. J. Anat., 65, 1 (1939).
7. T. Lewis, Heart, 15, 1 (1929).
8. K. Omoto, J. Anthropol. Soc. Nippon, 76, 122 (1968).
9. L. C. Rowntree and G. E. Brown, Am. J. Med. Sci., 170, 341 (1925).
10. T. W. Todd and L. Gorder, Am. J. Phys. Anthrop., 4, 239 (1921).