SUDORIFIC ACTION OF ADRENALIN ON THE HUMAN SWEAT GLANDS AND DETERMINATION OF THEIR EXCITABILITY [1]

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Although there is a vast amount of information concerning the responses of the human sweat glands to nervous, thermal, or chemical stimuli, our knowledge regarding the excitability of these glands is very scanty for lack of adequate methods of investigation. Numerous difficult problems of the physiology and pathology of the sweating mechanism, problems still unsolved, can be approached from a new angle by investigating the excitability of the sweat glands.

Recently we have devised a new method (3) which has two advantages over Minor's widely used method (1, 2): first, the sweat secretion from individual glands can be visualized directly by black spots at the sweat pores of the skin; second, the secretion in minute quantity can be detected with certainty by preventing its evaporation.

Our method will be described briefly. The area of the skin to be examined is painted with 2 or 3 per cent iodine-absolute alcohol solution and dried completely. Then this area is painted again with a mixture of 50 to 100 gm. fine starch powder and 100 cc. castor oil. For observations with great precision, it is desirable to limit the starch grains to about 10 μ in diameter. When sweating occurs, spots or rings of black-stained starch grains appear at the pores of functioning sweat glands and can be seen in a transparent layer of the starch-castor oil mixture, with the magnifying lens or naked eye. The usefulness of this method is illustrated in Figs. 1 and 2. The duration and cessation of sweating can be determined by repeatedly wiping the sweat spots with a dry cloth and painting with the starch-castor oil mixture. The secretion of sweat in such a small quantity as 0.000,05 mgm. from one gland suffices to make a sweat spot visible to the naked eye.

Beginning with the work of Elliott, a number of investigators have found a local inhibitory action of adrenalin on sponta-

[1] Reprinted verbatim, with permission, from *Science 111* (1950) 376-377, but with the addition of a second photograph supplied by the author.

neous sweating, but have failed to find its sudorific action on the human sweat glands. Thus, it has become accepted as general knowledge that human sweat glands are not stimulated by adrenalin and this has proved a basis for the concept that the sweat glands in man are innervated by the sympathetic cholinergic nerve fibers. On the other hand, some authors have reported that under certain conditions sweating is elicited by adrenalin, but these findings have been rejected or considered to be not convincing.

Contrary to the accepted view, we have recently demonstrated with certainty by our method a sudorific effect of adrenalin applied intradermally. Adrenalin hydrochloride solution (Sankyo Co., synthetic, $1:10^3$) was diluted with 0.9 per cent sodium chloride solution to various concentrations and 0.1 or 0.2 cc. was injected into the skin of the forearm, dorsum of the hand, or other regions of the body. With adrenalin of 1.10^3 to $1:10^4$, sweating began to appear over and around the injection wheal within 1 to 2 minutes after injection and spread progressively by forming processes or branches of sweat spots, along with expansion of the anemic area, showing diffusion of adrenalin via the lymphatic channels. As sweating became more evident, the sweat spots increased in size. This sweating response reached its maximum in 1 to 1½ hours and then declined until it ceased, 4 to 5 hours after injection. Local anemia generally persisted longer than the sweating. The extent and duration of sweating depended on the concentrations of adrenalin used. The minimal effective concentrations for causing sweating on the forearm of the majority of the young healthy subjects tested was $1:10^7$. With such a threshold concentration, the sweat spots disperse evenly over the original wheal of injection (see Figs.). The sudorific effect of adrenalin was not due to the fluid in which it was dissolved. Injections of 0.9 per cent NaCl solution or HCl solutions of pH corresponding to that of the adrenalin solutions were without effect. When adrenalin was destroyed by ultraviolet rays or by alkali, its stimulating action on the sweat glands was lost. The sweating response to adrenalin was not inhibited by atropine. Cocaine also had no influence on it.

By determining the minimal effective concentration of adrenalin applied intradermally, we have attempted to measure the excitability of the sweat glands (4). This was expressed as usual by the reciprocal (or its logarithm) of the threshold concentrations of adrenalin. The excitability of the glands on the

forearm thus measured was, as described above, 10^7 in more than 80 per cent of the healthy males and females tested, aged 14 to 24 years, and it was 10^6 in the remaining subjects. An excitability of 10^8 was rarely found. The sweat glands of the arm, leg, and trunk exhibited about the same excitability. No seasonal variation in the excitability was found, as measured by the adrenalin method, in the healthy adult subjects, at environmental temperatures of 4° to 27°C. In younger subjects, aged 1 to 12 years, and in older subjects aged 62 to 77 years, the excitability was found to be much lower. In the majority of the children of 1 to 5 years, sweating was not produced even with adrenalin of $1:10^4$. These findings indicate that the excitability of the human sweat glands reaches its highest level at the age of about 14 years in both sexes, but decreases in senility. However, it must be noted that the sweat glands of newborn infants tested within one week after birth exhibited almost the same excitability as that of their puerperal mothers (Nagashima). Whether some hormone or humoral agent exists for increasing the excitability of the sweat glands and maintaining it at high levels, remains to be decided by further investigations.

REFERENCES

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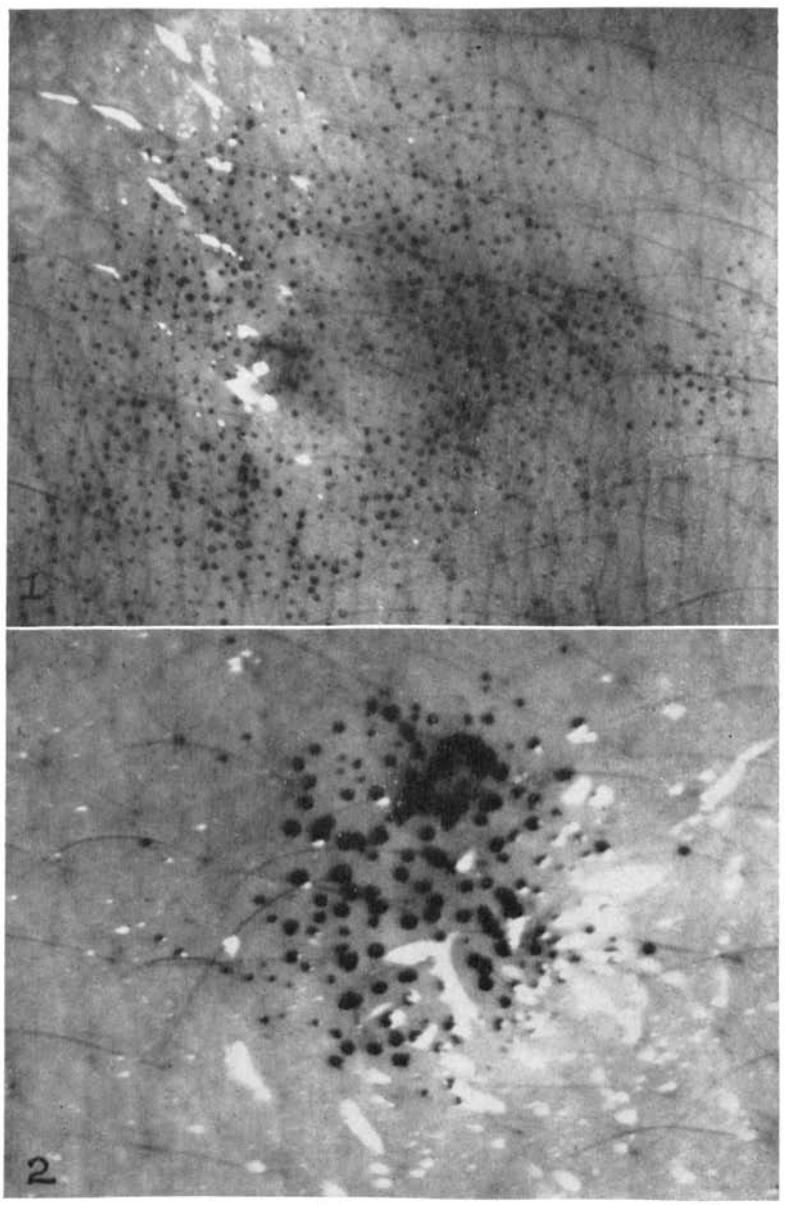
4. WADA, M. *et al.* Tohoku J. Exp. Med., in press.

DESCRIPTION OF PLATE

PLATE 13.

FIG. 1. Sweating response to injection of 0.2 cc. of adrenalin, $1:3x10^3$, on the forearm. Photographed 10 minutes after the injection; x4. Not retouched. The wheal at the point of injection is evident; the white spots and streaks are caused by reflection of light.

FIG. 2. Sweat spots at individual sweat pores of the extensor surface of the forearm following intradermal injection of adrenalin of $1:10^7$. Photographed 18 minutes after injection; x4. Not retouched. The white spots are caused by reflection of light.



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