DIFFUSION OF WATER THROUGH DEAD PLANTAR, PALMAR AND TORSAL HUMAN SKIN AND THROUGH TOE NAILS

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Since the observations of Erismann[1] in 1875 on the rate of diffusion of water through the skin of breasts and palms, studies of diffusion through dead human skin have been neglected and the rate of diffusion through toe nails has not been studied. In the study of insensible loss of water through the body and especially through the skin, it is important to know the relative ratio of water loss by diffusion through the skin of various portions of the body and nails.

MATERIALS AND METHODS

The rate of diffusion was measured for dead skin collected from bodies within a few hours (one to twenty-four, usually three to four) after death. Only healthy-looking skin of well nourished nonedematous bodies was used. The skins were collected from the following areas of separate bodies: epigastrium of 9 different bodies, axillas of 5, plantar surfaces of 10, palms of 3, and nails of the big toe of 5 others. In most instances several samples of skin and nail were collected from the same body. The causes of death of subjects varied considerably, including cerebral hemorrhage, accident (automobile), pneumonia, hepatitis, postpartal sepsis and chronic pulmonary tuberculosis. Occasional toe nails and plantar skin were collected from amputated feet.

The skins and nails were brought to the laboratory and mounted on a brass cylinder as shown in figure 1. The skin or nail was carefully prepared by the removal with surgical scissors of all fat, fibrous tissue and other subcutaneous and subungual tissue, leaving a relatively clean under surface. The skin or nail was then cut to cover the opening of the cylinder. It was then placed over the opening of the cylinder (*e*) which contained loose cotton and was filled with isotonic solution of sodium chloride. This solution filled the cylinders so that the fluid rested against the deep surface of the skin or nail. The cotton below provided means for the solution to keep in contact with the skin at all times, even with a decrease in the volume of fluid with evaporation. A brass ring (*b*) covered with a film of stopcock grease on the surface which came into contact with the skin was placed over the skin. Two pins soldered to the ring, 180 degrees from each other, were slipped into loose-fitting holes properly placed in the top of the cylinder (*e*). These pins prevented the brass ring and skin from twisting when the cap was screwed into place. The threaded portions were greased with stopcock grease. This tightly sealed a diaphragm of skin or of nail of 2 sq. cm. in area over the brass cylinder. This permitted loss of water only by diffusion through this known surface area of the skin or nail. Once the section of skin was in place the seal was kept intact, and the skin was not touched throughout all subsequent weighings. The skin or nail mounted on the cylinder was placed in a room brought to the desired temperature and relative humidity and allowed

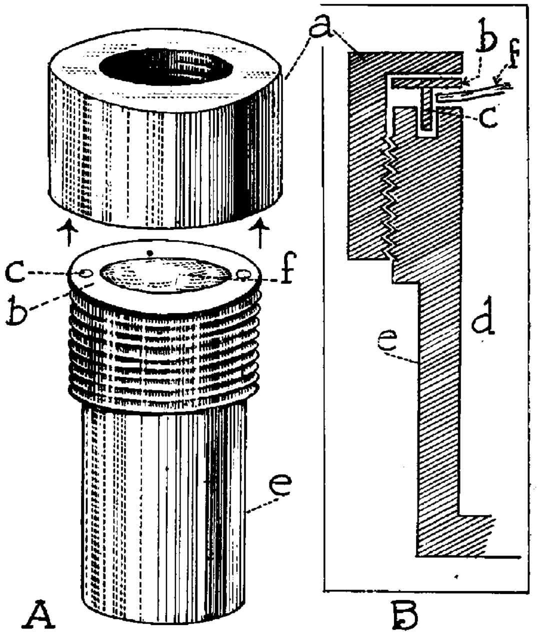

Fig. 1.—A diagram of the brass cylinders used for the measurement of the diffusion of water through dead skin. See text for details.

to dry for two to three hours. The metal cylinder with the tissue in place was weighed on an analytic balance to an accuracy of 0.1 mg. After a period of from a few minutes to twenty-four hours, usually four to five hours, the unit was weighed again. This was repeated several times for at least two successive days. Any loss in weight represented water lost by diffusion through the skin or toe nail. The temperature and relative humidity of the room were varied to produce a cool comfortable room or a hot and uncomfortable one. The absolute values of these are shown in figure 2. Some of the cylinders with skin or nail mounted in place were put in front

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1. Erismann, F.: Zur Physiologie der Wasserverdunstung von der Haut, Ztschr. f. Biol. **11**:1, 1875.

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of an ordinary electric fan at the various room temperatures and humidities in order to learn the influence of air currents on the rates of diffusion.

Some cylinders were filled respectively with whole blood, isotonic solution of sodium chloride and distilled water, with their surface exposed directly to the atmosphere.

In another study a piece of intact epigastric skin was placed over the cylinder and studied as previously described. Its corneous layer was then removed by gentle scraping and the rate of diffusion restudied.

One area of epigastric skin was observed continuously for sixty-one days under varying room conditions.

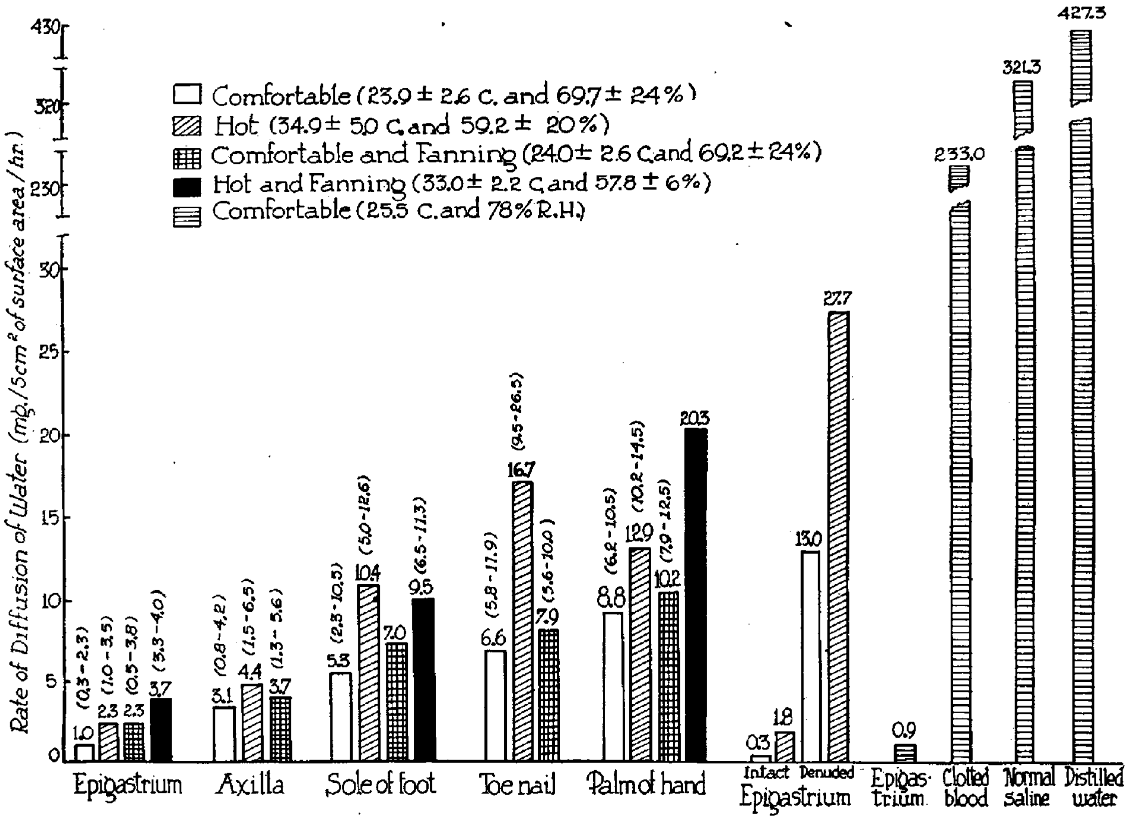

Fig. 2.—The rate of diffusion of water measured at various room conditions through skin from various portions of the body, including toe nails and intact epigastric skin immediately before and after denudation (removal of the corneum) and also from uncovered surfaces of fluids. The rate of diffusion of water through the epigastrium and the uncovered surfaces of fluids shown to the left of the figure were measured simultaneously under similar room conditions.

Many observations were made of each skin or nail for each room condition. Several hundred measurements were made in all, much too many to be presented in detail.

RESULTS

The results are summarized in figures 2 and 3. The absolute values are shown in the figures. The rate of diffusion of water through the epigastric skin was found to be much slower than that through any of the other skins or the toe nail. Diffusion of water took place most rapidly through the skin of the plantar and palmar surfaces. It occurred through the toe nail at a rate about equal to that through the plantar and palmar skins. Fanning increased the rate of diffusion of water as well as did an increase in temperature. A change in the humidity of the atmosphere did not produce as pronounced an influence on diffusion as did changes in temperature or air currents. An increase in the humidity of the air decreased the rate of diffusion.

Diffusion of water occurred much more rapidly through epigastric skin with its corneum removed than through intact skin (fig. 2). The rate was much more rapid from uncovered whole blood, isotonic solution of sodium chloride and

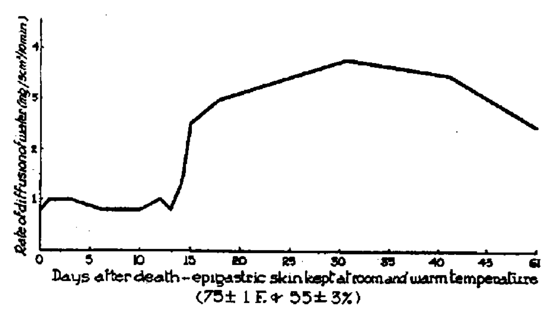

Fig. 3.—Variations in the rate of diffusion of water through a sample of skin from the epigastrium studied continuously for sixty-one days. The room conditions were: temperatures, 24 ± 2 C., and relative humidity,

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distilled water (these fluids are listed in an ascending order of the rates of diffusion of water) than through epigastric skin (fig. 2).

Figure 3 shows the influence of time on the inhibiting influence of skin to diffusion of water through it. The rate of diffusion changed little for the first two weeks; then it increased about three times, remaining at this level for the next six weeks. The rate of diffusion of water through this skin was still much slower than that through fresh plantar and palmar skin, toe nails or the aforementioned uncovered fluids even sixty-one days after death.

COMMENT

The observations indicate the great faculty possessed by human skin to inhibit diffusion of water. This is in keeping with observations in previous studies.[2] This property resides mainly in the corneum, as shown again in these studies. The cylinders containing whole blood, isotonic solution of sodium chloride and distilled water lost water at a rate greater than three hundred times that through epigastric skin.

The greater rate of water loss by diffusion through skin of the palms, soles and the toe nails is difficult to explain. The chemical and the histologic constitution of the entire skin and of the corneum, in particular of the palms and soles, are different from those of epigastric skin. How such differences might explain the striking differences in the rates of diffusion of water is unknown. The relative proportions of alpha and beta keratin in these tissues has not been determined; in fact, the physicochemical nature of skin is a much neglected aspect of biochemistry. The more rapid rate of diffusion of water through the skin of the palms and soles probably keeps these areas of skin slightly moist, thus facilitating the grasping of objects and walking. The difficulty one has in grasping objects securely when the palmar skin is dry is well known.

The epigastric skin studied for sixty-one days showed the prolonged efficiency of dead skin in the inhibition of diffusion of water. The fact that it changed little, even though pronounced digestive changes were noted in the underlying layers while the corneum merely wrinkled, is further proof that the corneum is the layer mainly responsible for the inhibition of the diffusion of water. The corneal layer is composed of dead cells even in intact living skin and therefore changes relatively little for several weeks after death. This layer has also been shown to be mainly responsible for the inhibition of diffusion of water in living intact skin.[2b]

The applications of these findings in health and in disease are obvious.

CONCLUSIONS

Our data support the following conclusions:

1. Diffusion of water occurs least rapidly through the skin of the epigastrium, most rapidly through the skin of the palms and soles and at a moderate rate through the skin of the axilla.

2. The rate of diffusion of water through the toe nail is essentially the same as that through the skin of the palms and soles.

3. Skin is an excellent barrier to the diffusion of water from the body, the corneum being the principle inhibiting layer.

4. Increases in temperature or air currents are especially effective in increasing diffusion, while changes in humidity of the air influence the rate of diffusion to a less extent.

5. Skin will retain its inhibiting influence on diffusion for many days (at least sixty-one days) after death provided the corneum remains intact.

We were assisted in these studies by M. G. Morgavi.

2. (*a*) Burch, G. E., and Winsor, T.: Rate of Insensible Perspiration (Diffusion of Water) Locally Through Living and Through Dead Human Skin, Arch. Int. Med. **74**:437 (Dec.) 1944. (*b*) Winsor, T., and Burch, G. E.: Differential Roles of Layers of Human Epigastric Skin on Diffusion Rate of Water, ibid. **74**: 428 (Dec.) 1944.

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