SIMULTANEOUS STUDY OF CONSTITUENTS OF URINE AND PERSPIRATION

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Although much attention has been directed to the study of the chemical components of human urine and blood with the aim of establishing relationships between the presence of certain bodies and variations in the percentages of the normal constituents with pathological disorders, few similar investigations have been conducted with perspiration. This is indeed surprising when it is considered that many dermatologists ascribe certain skin diseases to unknown chemical substances or to an abnormal balance of the usual constituents in the sweat.

Before any useful investigations on the influence of perspiration on the etiology of skin disorders can be scientifically instigated, more exact information as to the normal components of sweat is required and this is particularly true of the nitrogen fraction. The data on this subject are meager and much of the information is inexact and has been secured by methods hardly calculated to furnish reliable results.

As far as we are aware no complete analysis of the normal perspiration has been recorded. Individual components have been detected and in some cases their maximum and minimum limits established under certain specified conditions, but save for a few exceptions in which total solids, chlorides, non-protein nitrogen, and urea were simultaneously determined on the same sweat sample, almost all studies have been confined to one or two components. This is particularly true of the nitrogen fraction.

We were particularly interested in the non-protein nitrogenous fraction, the reaction of normal perspiration, and in those bodies producing the characteristic perspiratory odors. A correlation between the sweat and urine constituents during the period of test was also desired.

This has been made the subject of a similar investigation to the best of our knowledge only by Talbert and his coworkers. In a study extending over a number of years these investigators have found that sweat contains urea (1), uric acid (2), amino acids (3), ammonia (4), lactic acid (2), and sugar (5). The quantities of each of these components varied widely.

They found that perspiration normally contains between 0.24 and 1.12 mg. of urea per cc. Such values would account for from but 1.5 to 7 per cent of the urea eliminated through the skin daily, assuming a sweat secretion of 600 cc., and hardly are in accordance with Cramer's (6) estimate of 12 per cent. It is probable however that Talbert's figures are much lower than the normal values of the urea content in sweat. Riggs (7) has shown that as the flow of perspiration is stimulated and becomes more copious the organic matter in the fluid is reduced and is inversely proportional to the amount of sweat exuded through the skin. Talbert's samples were obtained by artificially inducing a flow from the sweat glands by pilocarpine and heat. Marshall (8), Barney (9), and others verified Talbert's value with samples obtained in a like or similar manner. In certain pathological disorders such as cholera and uremia the sweat glands may assume some of the functions of the kidneys and excrete urea of such quality that the entire skin surface is covered with very fine crystals (10).

Uric acid has been detected in sweat by a few experimenters but the amounts detected varied widely. Talbert and coworkers (2) and Voit (11) found very minute quantities in normal perspiration. Adler (12), on the other hand, detected very considerable quantities which in some cases reached the high figure of 30 mg. per 100 cc. According to Barney (9), uric acid was absent from the perspiration of the subjects that he studied.

The very accurate and sensitive amino acid determination methods of Folin (13) and of Van Slyke (14) have enabled experimenters to obtain very consistent results of the amino acid nitrogen content of perspiration. Talbert and coworkers (3), Embden and Tachau (15), and Neuberg (16) all report values ranging between 1.6 and 6.4 mg. per 100 cc.

Ammonia is an easily demonstrable component of perspiration and has been detected by all experimenters who sought its pres-

ence. Most of the nitrogenous bodies in sweat, however, are very easily fermented by bacterial and fungous agencies yielding ammonia; and, as most investigators of the composition of sweat have taken no care in obtaining or maintaining antiseptic conditions, it is probable that the ammonia contents reported are too high. Talbert and coworkers (4) obtained values of from 0.04 to 0.2 mg. per cc. and such values are about in accordance with the results of other experimenters.

The presence of creatinine and creatine in perspiration is still a controversial matter. Several investigators including Cramer (6), Capranica (17), and Schumann (18) have identified these end-products of protein metabolism in sweat samples and Schumann believes them to be normal constituents of human sweat. The amounts found were in no case large. Schumann believes that while creatinine is ordinarily present in amounts ranging from 3.5 to 5 mg. per cc. the creatine content is hardly greater than mere traces. Talbert and his coworkers (5) have been unable to secure any indication of either of these products, however.

Other non-protein nitrogenous substances have been reported as having been isolated from perspiration but the nature of the compounds described justifies the belief that they are chance contaminants and not ordinary normal or abnormal sweat constituents. It is probable that minute traces of the purines and other nitrogenous bodies are present in sweat and that the character of these products is as complicated and diversified as in urine itself.

The chemical reaction of perspiration has been made the subject of a considerable number of studies. Most experimenters have found human sweat slightly acid and some relationship between this reaction and dermatological disorders has been reported. However, the connection is by no means conclusive and might as readily be attributed to other causes. Owing to inaccuracies in measuring acidity, much of the early work is almost valueless, and even the results of later investigators show such variations as to render the conclusion that the reaction of sweat is a very variable factor inevitable. However, it has been pointed out first by Schiefferdecker (19) and later by Fishberg and Bierman (20) that sweat may be secreted from two different types of glands, which has been called exocrine and apocrine sweat. These fluids vary considerably in composition and reaction and their flow is

stimulated by different incitants. It is probable that the variations in the relative degree of acidity reported by different experimenters can be partially explained by different ratios of the two types of sweat in the samples. According to different investigators, the pH of perspiration may vary from 3.4 to 8.4.

Sugar has been identified in perspiration by Talbert and his coworkers (5), Usher and Rabinowitch (21), Sutton and Sutton (22), Cornbleet and Montgomery (23), and others and appears to be a normal constituent of this fluid. It is largely due to this substance that sweat acts as an excellent culture medium for bacteria, fungi, and other microorganisms. This fact may prove of interest in bacterial skin infections. The percentage of sugar in the perspiration is generally low, ranging from 2.8 to 50 mg. per 100 cc. of sweat. Diabetic patients, as might be expected, have a much higher percentage of sugar in their perspiration than has the normal individual (24) and are more prone, as a natural corollary, to fungous skin infections.

Lactic acid and lactates are present in all sweat and the amount appears to vary with the amount of exercise taken by the subject immediately before collecting the samples. Krestownikoff (25) found that the average individual's perspiration contained about 15 mg. per 100 cc. but increased rapidly during participation in sport and might reach values of over 100 mg. Koriakina and Krestownikoff (26) found 1765 mg. of lactic acid per 100 cc. in the sweat of Marathon runners. Talbert, on the other hand, found that the lactic acid content of sweat in the average person was considerably higher than Krestownikoff's figure, ranging from 71 to 160 mg. per 100 cc.

The mineral bodies consist chiefly of sodium chloride, alkali sulfate, phosphates, and unknown complexes of calcium and magnesium (20, 27). The relative amounts of these in perspiration are said to differ materially from those in urine (28). Most of the sulfur is present not as the inorganic sulfate but as ethereal sulfuric acid esters. The chloride content varies enormously with the subject and seems to bear some relation to diet and individual idiosyncrasies. Talbert and Haugen (29) found the limits to range in the subjects that he studied between 420 and 660 mg. per 100 cc. These values roughly approximate those secured by other observers (30, 31), though results as high as 2 per cent have been recorded.

A study of the composite information on perspiratory components indicates that perhaps a very close physiological relationship exists between urine and sweat. Both fluids contain many of the same chemical substances and have a similar acid reaction, and it might be deduced would have a similar effect upon the skin.

However, the chemical data on sweat are too incomplete to permit of accurate postulations. We have been unable to discover any record of a complete chemical analysis of the non-protein nitrogenous end-products of protein metabolism in sweat samples, or data which would furnish a daily average of any single component. Samples collected at a specified time record only the composition of the perspiration exuded at that period and may only roughly indicate the average. It is well known that urine varies greatly throughout the day and a true average is only obtainable upon the collection of all voided during a 24 hour period. The same condition probably exists with sweat.

All of the tests described in the literature on perspiration composition were made with specimens collected under aseptic conditions. Sweat is an easily fermentable fluid, being readily changed by bacterial and fungous agencies. While such changes may not produce any great variations with more concentrated solutions, the minute quantities of such nitrogenous substances as uric acid and creatinine occurring in sweat may be largely converted into other bodies during the time required to collect the samples.

Most experimenters have collected their samples by placing the subject in rubber sheets or enclosing a portion of the subject's anatomy with some type of rubber jacket. No indication exists from their articles on the subject that any particular precautions were exercised to prevent vitiation of the samples by rubber-extracted material. Almost all rubber sheets and articles of rubber construction contain small amounts of sweat-soluble matter which may be acid or alkaline depending upon whether the crude rubber from which the rubber has been derived was acidic or basic, and upon the nature of those auxiliaries used in the manufacture of rubber sheet. These rubber extractives might profoundly influence the analysis of the materials collected unless the rubber had been specially treated to remove soluble matter.

In our study of the urinary and perspiratory products three

males in excellent physical and normal mental condition were selected as the subjects for investigation. All maintained their normal routine during the period of test. No dietary changes were prescribed and no effort made to control their moisture intakes. The investigation was of but 2 days duration.

All urine voided by each subject was collected separately and furnished two 24 hour samples. The collection receptacles contained a small amount of C.P. chloroform to prevent decomposition.

Samples of perspiration were collected from each subject three times daily, at 9 a.m. and at 3 and 11 p.m. It was felt that the mean of the three would furnish a value approximating rather closely the daily average of the sweat composition of each subject. Immediately after the collection of the morning and afternoon samples, they were submitted to chemical analysis. The night sample was preserved with a few additional drops of chloroform and refrigerated until the next morning. About 200 cc. of perspiration were collected from each subject at each sweating operation.

The bodies of the patients, prior to the collection of the samples, were very thoroughly washed with warm water in order to remove soluble matter and loosely adherent dirt and cutaneous bodies. Possible urinary contaminations of the sweat samples were prevented by encasing the excretory organs of the subjects in tight fitting rubber caps prior to the collection of the perspiration.

The subjects were then introduced into a sweat chamber maintained between 40–50° and placed on special beds, the mattresses of which were covered with tautly stretched purified rubber sheets which gently sloped from the sides to the center. At the low points glass tubings pierced the mattresses and were attached to the sheets, which had small holes at these points. The lower ends of the glass tubes communicated with receptacles for sweat collection, containing a few drops of C.P. chloroform. The patients were covered with purified rubber sheets and finally with blankets. As sweat was exuded from the bodies of the patients, it gradually flowed to the low point of the lower sheet and into the receptacle below. In this manner, bacterial and fungous decomposition of the non-protein nitrogenous matter of the perspiration was largely arrested.

It was found that from ½ hour to 50 minutes were required to

secure the 250 cc. of sweat required for the determination. No pilocarpine or other sweat-stimulating agents were employed to induce more copious sweating.

The rubber sheets were prepared from pure crêpe rubber and were washed until they were found free from all sweat-soluble extractives by determination.

Both the urine and sweat were analyzed for total solids, chlorides, sulfates, organic matter, non-protein nitrogen, sugar, lactic acid, and the non-protein nitrogen fractions urea, uric acid, ammonia, amino acid nitrogen, creatinine, and creatine.

The total solids were determined by evaporating 5 cc. samples to constant weight at 80°. Organic matter was found in accordance with the conventional technique on the evaporated material employed from the total solid determination.

Chlorides were found by precipitating the chlorine in the ashed samples with standard silver nitrate solutions and titrating the excess with standard ammonium sulfocyanate, with ferric ammonium sulfate as an indicator.

Sulfates were determined by the conventional barium chloride procedure.

The customary procedures of Folin and coworkers (13, 32) were utilized in establishing the contents of the sugar and non-protein nitrogenous components of the sweat. Minor modifications were adopted in certain procedures but these consisted chiefly in avoiding dilution of the sweat, which is a very dilute solution.

The lactic acid content of the sweat was determined by the gasometric method of Avery and Hastings (33). Unfortunately, the determination of this component in urine did not prove satisfactory and the results are not included in this paper. Whether our inability to obtain accurate lactic acid values in urine was due to faulty technique, undetermined impurities in the urine, or some other cause was not investigated.

The results of the analysis are recorded in Table I. All results on sweat are the mean from the three samples from each subject collected daily. We were unable to establish any quantitative correlation between the urinary and perspiratory components. Accordingly, the urinary analyses are not included in Table I, as they show nothing novel.

The results on the amounts of the individual components of the

human sweat samples are about in accordance with values reported on individual determinations by other observers. We did, however, secure a relatively higher percentage of the non-protein nitrogen fraction as urea and a correspondingly lower amount of ammonia. We are inclined to attribute this to efforts made to prevent alterations in the sweat by bacterial and fungous agencies during the period of time required for collecting the samples. Both the uric acid and creatinine fractions of the sweat were quite

TABLE I

Composition of Sweat and Urine

Subject A, male, 28 years of age. Subject B, male, 39 years. Subject C, male, 36 years.

All results are computed as mg. per 100 cc. of fluid.

	Sweat						Urine, average of all on both days
	Subject A		Subject B		Subject C		
Day	1	2	1	2	1	2	
Amount collected, *cc.*	583	540	470	440	534	498	6870
pH	5.42	5.65	5.02	5.18	5.71	5.47	5.91
Total solids	1380	1305	1280	1174	1597	1207	4365
Mineral matter	1027	985	991	821	1170	890	2300
Chlorides (Cl)	582	576	508	395	602	485	938
Sulfates (SO_4)	12	8	7	5	4	17	240
Non-protein N	75	66	81	77	108	86	1006
Urea N	50	40	56	51	81	62	814
Ammonia N	11	8	15	8	11	14	34
Uric acid N	0.4	0.3	0.2	0.2	0.5	0.3	43
Creatinine "	0.8	0.7	0.2	0.5	0.7	0.5	58
Creatine N	None	Trace	None	None	Trace	Trace	6
Amino acid N	3.1	2.4	3.3	2.9	3.7	2.9	13.7
Sugar	21	6	8	18	22	16	71
Lactic acid	94	107	34	58	78	71	Present

low and present in hardly more than traces. Our results regarding the uric acid of perspiration confirms the work of Talbert and his coworkers and the experiments of Voit. Qualitatively our results confirm those of Schumann regarding the presence of creatinine in sweat, though our values were much lower than any he records.

SUMMARY

Qualitatively perspiration was found very similar to urine in composition, though the relative amounts of the various com-

ponents in the two solutions varied considerably. Urine is a much more concentrated solution, containing from 3 to 5 times the amount of total solids and from 5 to 9 times the amount of organic matter.

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