The Loss of Calcium, Phosphorus, Iron, and Nitrogen in Hair from the Scalp of Women

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WHEN BALANCE studies are used to assess the iron, calcium, phosphorus, and nitrogen requirements of human adults, the question arises as to how much of each element must be retained to cover the small losses. Among these losses are those from hair, including that on the scalp, on the skin and on axillary, pubic, and other areas. The present study was planned to determine the losses of iron, calcium, phosphorus, and nitrogen attributable to the loss of hair from the scalp. Determinations have been made of these four elements in hair by a few workers who have reported widely different values for the three minerals. As far as the authors have been able to ascertain, no study has been made of the weight of hair lost from the scalp.

PROCEDURE

Twelve women 18 through 22 years of age and one 54 years of age served as subjects. The young women collected hair combings daily over a period of four weeks with the exception of Sundays and the older subject for twelve six-day weeks. Each subject wore a hair net night and day and combed her hair in the laboratory while wearing a plastic cape and standing on a plastic sheet. All shampooing during the combing collection period was conducted at the laboratory and the water used in the process was strained through a cloth filter to catch the hair in it. Hair collected during shampooing was regarded as combings. Three hair trimmings were conducted at the laboratory for each subject who customarily had her hair cut. The plastic covers and sheets used during cutting were hung from a rod, the cuttings washed into a trough and the water filtered through a cloth. The hairs were picked off the plastic protectors and the cloth filters with tweezers. For the older woman the hair was collected from all shampoos, nine in number, from October, 1955 through May, 1956 and from two permanent waves. Her hair was cut only at the time the permanent waves were given and the collection represented all the cuttings for an entire year.

Most of the hair collection from each subject was washed twice in a 2 per cent soap solution made with hot distilled water, and thoroughly rinsed. The rest of the hair, enough for the iron determinations, was washed twice in a hot solution of a liquid synthetic detergent designated as "shampoo A." Two teaspoonfuls of shampoo A were used with each 100 ml of distilled water. The hair was allowed to soak in the shampoo solution overnight; it was then rinsed. The wash-waters were filtered through cloth. The tiny bits of hair which were collected on it were used in the determinations of the total weight of hair-loss but not for the determination of nutrients.

The rinsed hair was dried at 90 to 95° C until it reached a constant weight. The operation was time-consuming because the hair was so hygroscopic that drying was not effective on humid days. Three samples of hair of a weight appropriate for the particular nutrient or nutrients under study were placed in weighing bottles and the hair again heated to a constant weight. For the determination of nitrogen the hair was transferred to 100 ml Kjeldahl flasks; for the minerals it was transferred to platinum dishes and ashed at 500° C.

Nitrogen was determined by a semi-micro Kjeldahl method in which selenium was the catalyst; the ammonia was distilled with steam into a solution of boric acid. The ash for the

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determination of the mineral elements was dissolved in dilute HCl, then concentrated HCl was added. The solution was heated to dryness on a steam bath and the ash removed from the dishes with a solution of HCl. Iron was determined by the ortho-phenanthroline method using sulfurous acid for the reducing agent as recommended by Dutcher and Rothman.[1] Calcium was determined according to the micromethod for plants as given in the Official Methods of Analysis of the A. O. A. C. 1955.[2] Phosphorus was determined by the method of Simmons and Robertson.[3]

Determinations of the four nutrients were made on cuttings, except for the one subject who did not cut her hair. In her case all determinations were made on combings. A few determinations were made on combings collected from other subjects.

A few samples of the subject's hair and a few samples of hair obtained from a beauty parlor were used to study the effect of several commercial shampooing preparations and one soap.

In order to calculate the annual loss of hair records were kept of the date of each shampoo over a period of three months and of each of three consecutive trimmings. The assumption was made that the frequency of shampooing and trimming would be the same during the rest of the year as during the interval when records were kept.

RESULTS AND DISCUSSION

The total weight of hair lost in combing, shampooing, and trimming the hair from the heads of 12 young women varied from 41.36 to 105.96 g/year (Table I). The mean loss for the 12 subjects was 70.73 g. The two subjects with the largest losses had thick hair; the hair was also coarse as scored by five judges. The three subjects with the smallest losses had the finest hair. All losses of hair reported may be considered minimum because occasional hairs were no doubt lost through the hair nets.

The loss of 49.18 g/year by the subject who was 54 years of age, and who was included because more complete collections were available than for the younger women, fell within the range of the losses of the younger group. According to Myers and Hamilton[4] the hair on the scalp grows faster at ages 45 to 52 than at 21 to 30 years. According to Müller[5] hair does not grow to its full length after 35 years of age

TABLE I

Annual Loss of Hair from the Scalps of 13 Women and the Content of the Hair in Four Nutrients

Subject	Hair color	Content of 100 g of hair*				Annual loss†				
							Nutrients contained in hair			
		Ca mg	P mg	Fe mg	N g	Hair g	Ca mg	P mg	Fe mg	N g
P. F.	Dark brown	175	13.3	1.28	15.6	105.96	172	14.1	1.42	16.5
J. W.	Dark brown	104	17.5	1.67	15.8	103.32	108	18.1	1.72	16.3
J. H.	Blonde	205	11.4	1.95	15.2	87.12	179	9.9	1.70	13.2
S. W.	Light brown	198	12.9	1.52	15.9	86.59	172	11.2	1.31	13.8
S. T.	Red	224	11.2	2.43	14.5	78.27	143	9.1	1.76	11.4
H. C.	Medium brown	78	14.2	1.41	15.8	70.92	51	10.1	1.00	11.2
K. S.	Red	13	13.0	1.96	16.6	68.81	9	9.0	1.35	11.4
A. R.	Dark brown	45	13.5	1.35	16.4	57.57	26	7.8	0.78	9.4
N. V.	Red	62	17.2	1.39	15.9	52.72	33	9.1	0.73	8.4
S. K.	Blonde	58	14.2	1.53	16.2	48.24	28	6.8	0.74	7.8
A. S.	Medium brown	161	13.8	1.78	16.3	47.91	77	6.6	0.82	7.8
M. S.	Medium brown	200	11.5	3.28	14.7	41.36	83	4.8	1.36	6.1
Mean		127	13.6	1.80	15.7	70.73	90	9.7	1.22	11.1
S. D.		74.4	2.02	0.572	0.65	21.890	63.2	3.56	0.396	3.37
Z.	Medium brown and gray	71	13.3	1.24	15.7	49.18	26	6.5	0.72	7.7

* All values for calcium, phosphorus, and iron are for determinations made on cuttings except in the case of J. H. who did not cut her hair. Values for her hair were determined on combings.

† The annual loss was calculated from values for combings as well as cuttings in a few cases in which values for the nutrient content of combings was determined.

and Flesch,[6] in a review of hair growth, states that hair becomes larger in diameter with age.

In considering the total loss of hair the loss from parts of the body other than the head must be taken into consideration. Short hairs, the loss of which is too large to neglect, are found on all but a few areas. Myers and Hamilton[4] found that the period of regeneration and the life span of the hairs from the other areas are shorter than for hair on the scalp, but the rate of growth is slightly slower (except for hairs on the chins of men). The total amount of body hair varies widely with age and sex and from person to person.

The mean calcium content of the hair of the 12 subjects was 127 mg per 100 g. The content varied widely from subject to subject, from as little as 13 up to as much as 224 mg (Table I). Other workers, too, have found a wide range. Ikeuchi[7] noted a range of 65 to 157 mg and Goldblum, Derby and Lerner[8] from 70 to 490 mg. The low mean value of 20.8 mg found by Bagchi and Ganguly[9] may have been occasioned by the treatment with hot dilute HCl in the cleaning process. A reason for the wide range will be discussed later.

The phosphorus content ranged from 11.2 to 17.5 mg/100 g (Table I). This was a little higher than the range of 2.6 to 14.0 mg found by Goldblum, Derby, and Lerner,[8] but considerably below the mean of 80 mg found by Bagchi and Ganguly.[9]

The mean iron content of the hair from 12 subjects with blond, brown, and red hair was 1.80 mg/100 g; the range was from 1.28 to 3.28 mg (Table I). These values are far below that of 14.10 mg found by Bagchi and Ganguly[9] for black hair, and far higher than the values of 0.11 mg for blond and 0.68 for medium brown hair by Kikkawa, Ogita and Fujito.[10] The latter workers reported 2.9 mg for black hair. The values found in the present study are slightly higher than those of 0.08 to 1.1 mg of Goldblum, Derby, and Lerner[8] and slightly lower than the values of Dutcher and Rothman.[1] The latter workers reported 2.71 mg for black hair, 2.43 mg for blond hair, and a mean of 9.78 mg for three subjects with red hair. Red hair was found not to be exceptionally high in iron in the present study. A few samples were wet-ashed by the method used by Dutcher and Rothman,[1] but this did not alter the results.

The mean nitrogen content of the hair was 15.7 ± 0.65 g per 100 g. This is similar to values of 15.8, 16.3, 15.4, and 14.6 g found by Rutherford and Hawk;[11] Stary;[12] Clay, Cook, and Routh;[13] and Bagchi and Ganguly,[9] respectively.

In some subjects the color and texture of the cuttings differed from the combings. This suggested that a difference may exist in composition. Each hair has a growth period and then is retained for a while after it has severed connections with the hair follicle. Combings may contain a relatively high proportion of hairs which have ceased to grow, are older than the other hairs, and have been shampooed more times. The color difference was particularly striking in the case of subject S. T.; her cuttings were bright red and her combings a dull gray-brown. The calcium, phosphorus, and iron contents of her cutting were 224, 11.2, 2.43 mg/100 g, respectively, and of the combings 107, 12.5, and 1.90 mg. Since the difference in the calcium and iron content was large, samples from other subjects were studied. In the case of subject P. F. the cuttings contained 175 and the combings 142 mg of calcium per 100 g of hair. For two subjects the phosphorus content of cuttings and combings was similar. The difference between the amount of iron in the cuttings and combings of the other subjects was small; in one case the quantity of iron in the combings slightly exceeded that in the cuttings.

The mean annual loss of calcium, phosphorus, and iron in the combined combings and cuttings of the twelve young women was 90, 9.7, and 1.22 mg, respectively (Table I). This means that the average woman would need to retain from her food 0.35 mg of calcium, 0.04 mg of phosphorus, and 0.005 mg of iron a day to compensate for the loss. The mean annual loss of nitrogen was 11.1 g/year (Table I); thus each day 0.043 g would be lost and that amount would need to be retained from the food. Experience in this laboratory shows that young women retain approximately 0.6 g of nitrogen a day on intakes of about 60 g

of protein. About one-fourteenth of this would be required to cover the loss of nitrogen in the hair from the scalp. If the assumption is made that adult women are in nitrogen equilibrium when all the small losses are included, this figure is reasonable since additional losses include those in hair from other parts of the body as well as losses in nails, skin, perspiration, saliva, tears, nasal excretions, and menses.

The above values do not consider the possible loss of nutrients other than those present in the hair at the time it is cut or removed by combing. The removal of nutrients during shampooing is the most obvious possible other cause of loss.

A problem encountered during the study was that of how to remove calcium deposited on the surface of hair during shampooing in calcium-containing water, if such a deposition occurs, and yet not remove the calcium which is a constituent of the hair. If hair is soaked in dilute HCl almost all the calcium is removed from it; this was not done. In the early analyses made during the present study, the calcium content of hair washed in a 2 per cent soap solution was higher than that in hair washed with either commercial shampooing preparations A or B (Table II). In later studies in which the cuttings from subjects P. F. and J. W. were washed once in soap then five times in soap or shampoos A and E, about the same amount of calcium was removed (Table II). In the latter studies the treatment was rather severe: each of the six washings included stirring the hair in the washing solution, with two footed glass rods, lifting the hair to another dish, washing with fresh solution, and finally rinsing several times in distilled water.

TABLE II

The Effect of Shampooing on the Calcium, Phosphorus and Iron Content of Hair

Sample of hair*	Washing procedure	Ca	P	Fe
		Mg per 100 g of hair		
A	Once in soap	273	12.4	1.6
	Once in shampoo A	207	13.0	1.8
	Once in shampoo B	207	12.3	1.7
Z	Once in soap, then			
	No additional treatment	—	13.1	0.9
	Soaked overnight in shampoo A	—	11.4	1.1
	Washed 10 times in shampoo A	0	10.8	2.2
J. W.	Five times in shampoo A	36	14.5	1.4
	Five times in shampoo C	36	14.5	0.9
B	Soaked overnight in shampoo A	—	11.5	1.7
	Washed 5 times in shampoo A	—	11.5	1.9
C	Once in soap	329	—	—
	Once in shampoo A	305	—	—
D	Once in soap	104	12.1	0.8
	Once in shampoo D and sprayed with a curl set	38	12.2	0.9
P. F.	Once in soap, then			
	Five times in soap	69	10.0	1.06
	Five times in shampoo A	63	10.2	1.07
	Five times in shampoo E	58	10.7	0.96
J. W.	Once in soap, then			
	Five times in soap	34	12.9	1.00
	Five times in shampoo A	43	14.7	1.42
	Five times in shampoo E	38	14.1	0.92

* Samples A, B, C, D are cuttings obtained from a beauty parlor. The other samples are cuttings obtained from subjects.

The continued washing of hair with either soap or commercial shampooing preparations and distilled water reduces the calcium content. After washing once in soap the hair of subject P. F. contained 175 mg of calcium/100 g of hair (Table I) but after washing six times it contained 69 mg (Table II). With similar treatment the calcium content of subject J. W.'s hair fell from 104 to 34 mg. No experimental washings of cuttings were made in which hair was washed in tap water. Whether the calcium content of tap water would reduce the loss of calcium is not known.

If washing in solutions of shampooing preparations in tap water (the procedure used by the subjects when they washed their hair) removes calcium from hair, the subjects must have removed a considerable amount in that way since most of them washed their hair frequently. Of the 12 young women six shampooed their hair about once a week and the others more often. Subject K. S., whose hair had the lowest calcium content, washed her hair once a week with shampoo A and subject A. R. with the second lowest calcium content had been washing her hair every three or four days with shampoo D, then spraying it with a pin curl set. When samples of hair cuttings

obtained from a beauty parlor were washed with shampoo D in distilled water and rinsed with the set used by subject A. R., the calcium content was about a third of that found in samples washed once in soap (Table II).

The 12 subjects had been using nine different shampooing preparations; four subjects had been using a rinse or set in addition. No differences in the amount of calcium removed by commercial shampooing preparations were noted in the limited tests made in this study. Whether the pH of the washing solution had an effect on the amount of calcium removed is not known. One washing of cuttings in a soap solution made with distilled water left more calcium on or in the hair than the prepared shampoos. The pH of the soap solution was approximately 10 while that of shampoo A was 6 and that of the other preparations ranged from about 7 to 8.

The phosphorus content of the hair was reduced less than that of calcium by repeated washing procedures. After one washing in soap the phosphorus content of the hair of subject P. F. was 13.3 mg/100 g (Table I); after six washings it contained 10.0 mg (Table II). Similar treatment of cuttings from subject J. W. caused the phosphorus content to fall from 17.5 to 12.9 mg.

As far as iron is concerned, hair washed in shampoo A usually contained more iron than hair washed in soap. The differences were small except when hair was washed ten times in shampoo A which raised the iron content from 0.9 to 2.2 mg/100 g (Table II). The reason for this is not known. The shampoo contained only a trace of iron so the higher iron content of the hair could be accounted for only if practically all the iron in the solution migrated to the hair. Since washing removes fat and the samples were weighed after washing, some concentration of the iron content may have occurred. Why concentration might occur in the case of iron and not of phosphorus can only be explained by the removal of some phosphorus as well as fat during repeated washing.

Commercial shampooing preparations may affect the iron content of hair differently. The use of shampoo A gave the hair a slightly higher iron content than was obtained with shampoo B, but the difference was so small as to be within the error of the method (Table II). Shampoo A yielded hair containing considerably more iron than that found in hair washed with shampoo C but hair from only one subject (J. W.) was tested (Table II); the iron content of hair washed in shampoo A was also greater than that found when shampoo E was used, the increase being slight for one subject (P. F.) but considerable for another (J. W.) (Table II). Whether the use of soap or some other constituent or constituents in shampooing preparations accounts for the effect on the iron content of hair is not known. Shampoo A contained synthetic detergent only; B was part soap and part synthetic detergent; the composition of C and E is not known to the authors.

SUMMARY

Twelve women, 18 through 22 years of age, and one woman, 54 years of age, collected hair from the scalp. Combings for four six-day periods, shampoo losses during 28 days, and hair cuttings from three trimmings were collected by the young women. Collections over longer periods of time were made by the older woman. The mean annual loss of hair, after washing and drying at 90–95° C, was 70.73 g/person/year for the young women; the range was from 41.36 to 105.96 g. The older woman lost 49.18 g. The loss of hair reported here was minimum because a little undoubtedly escaped through the hair net worn during the combing-collection periods. The value does not include hair lost from other parts of the body.

The mean content per 100 g of hair for each of 12 young women was 127 ± 74.4 mg of calcium, 13.6 ± 2.02 mg of phosphorus, 1.80 ± 0.572 mg of iron, and 15.7 ± 0.65 g of nitrogen. The mean annual loss for each young woman was 90 mg of calcium, 9.7 mg of phosphorus, 1.22 mg of iron and 11.1 g of nitrogen. The annual losses of the older woman were within the range for the others.

The figures here reported for the annual loss of nutrients by way of the hair may be too small because some nutrients, especially cal-

cium, may be lost from hair during shampooing. The type of preparation used for shampooing may affect the loss of minerals: a certain soap removed less calcium than a certain commercial shampoo, when hair was washed once in each, and one commercial shampoo had the effect of either adding iron to hair or causing the retention of more iron than soap and certain other commercial shampoos.

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