Acta Paediatrica Hungarica, 25 (3), pp. 299—307 (1984)

Zinc, copper, manganese and gold content of the hair of infants

E Kauf,[1] W Wiesner,[2] S Niese,[2] W Plenert[1]

[1] Department of Paediatrics, University of Jena; and
[2] Central Institute of Nuclear Research, Academy of Sciences, Rossendorf, GDR

In the hair of 41 normal newborn children the amounts of the trace elements zinc, copper, manganese and gold were followed up longitudinally by neutron activation analysis, the samples being taken on the 1st day of life, between the 63th and 109th days, the 200th and 240 th as well as between the 368th and 478th days of life. In the newborn children no correlations among their hair trace elements themselves and with the duration of normal pregnancy, birth weight, weight percentiles according to Lubchenko et al. [21] and birth length were found. The zinc content of 212 $\pm$ 63 ppm, the copper content of 8.1 $\pm$ 2.3 ppm and the manganese content of 0.211 $\pm$ 0.366 ppm agreed well with values in the literature from different parts of the world. The hair gold content was found to be 0.086 $\pm$ 0.006 ppm. In early childhood the trace element contents do not exhibit any dependence on sex.

The investigation of trace elements in the hair of babies resulted in the remarkable observation that in the first three months of life zinc, copper and gold contents shows a considerable increase to multiple levels of the birth values, followed by a decrease. This is important for the interpretation of hair trace element analyses in infants. There are significant positive correlations among zinc, copper and gold contents in hair. It must be emphasized that gold, although classified as a non-essential element, behaves in the hair of infants just like the physiologically important essential trace elements zinc and copper. In contrast, in the case of manganese there were neither such dynamics nor a significant correlation with the other hair trace elements, and with age, body weight and length.

So far 15 trace elements (Fe, Cu, Zn, Mn, Mg, Co, Cr, Ni, V, Se, F, J, As, Sb, Si) have been identified as essential parts of mammalian organisms [26]. One possibility among others is to investigate the individual status of the intake of selected trace elements (e.g. zinc, copper and manganese) by elementary analysis of human [19, 20] or animal hair [1]. Hambidge et al. [14] consider hair zinc contents below 70 ppm in the case of children to be suggestive of a general lack of zinc in the body. Only few results have been obtained from newborn children and infants, whereby review studies in respect to different age groups have been compiled [4, 7, 14, 15, 29]. We studied the trace element contents in human hair with grow-

This work is part of the research programme on biological sciences HFR of the German Democratic Republic. It is a contribution to a coordinated research project of the IAEA, Vienna.

ing age, starting from birth, in order to assess variability and reliability of hair used as an indicator.

Materials and Method

From a group of 41 children (birth weight >2500 g with a mean of 3269±330 g, normotrophic according to Lubchenco et al [21] pregnancy of 37—42 weeks without any complication, 20 boys and 21 girls) hair samples were taken with the help of stainless steel scissors. The back of the head and the neck were the regions involved. The time was the first day after birth. Further samples (whole length of hair) were taken from the same individuals under similar conditions after 63—109 days (mean 83±14 days), 200—240 (224±±15) days as well as after 368—478 (402±33) days.

All samples (weight 7—50 mg) were filled immediately into plastic tubes, washed according to the instructions of IAEA [25], dried at a temperature of 80°C for 2 h and weighed into quartz ampoules. The material pretreated in this way and standard samples of zinc, copper, manganese and gold were packed into quartz containers. After sealing, they were irradiated for one hour with a thermal flux density of $6-8\times10^{13}$ neutrons · · $cm^{-2}s^{-1}$ in the Rossendorf research reactor. Activity measurements by gamma-spectrometry were carried out with an 18 cm^3-Ge(Li)-detector and a 4096-channel memory. An extensive representation of the method was given previously [30].

Statistics

Due to the rather poor sampling neither a normal distribution nor a normal logarithmic distribution could be proved with satisfactory

Table I

Zinc, copper, manganese and gold contents in the hair of newborn children, ppm

		n	$\bar{x}$ arithm ± arithm	Median	$\bar{g}$ geometr	$\overset{x}{:}$ S geometr
Zinc	Male	20	204.0 ±42.0	192.0 (144.5—338.1)	201.0	1.15
	Female	21	219.0 ±79.0	192.0 (150.7 —456.2)	209.0	1.26
	Total	41	212.0 ±63.0	193.0 (144.5 —456.2)	205.0	1.21
Copper	Male	20	8.6 ± 3.1	7.8 (6.71 — 21.3)	8.3	1.16
	Female	21	7.7 ± 1.1	7.4 (6.1 — 10.9)	7.6	1.11
Manganese	Male	14	0.20 ± 0.35	0.09 (0.04 — 1.40)	0.11	2.24
	Female	18	0.22 ± 0.39	0.09 (0.04 — 1.42)	0.11	2.68
	Total	32	0.21 ± 0.37	0.09 (0.04 — 1.42)	0.11	2.49
Gold	Male	20	0.009± 0.006	0.006 (0.002—0.021)	0.007	1.99
	Female	21	0.009± 0.006	0.008 (0.002—0.025)	0.007	1.97
	Total	41	0.009± 0.006	0.007 (0.002—0.025)	0.007	1.99

Table II

Rank correlation coefficients (Spearman) of hair zinc, copper, manganese and gold contents of newborn children in respect to duration of pregnancy, birth length, birth weight and weight percentile according to Lubchenco et al [21]

	Zinc	Copper	Manganese	Gold	Duration of pregnancy	birth length	Birth weight	Weight percentile
Zinc	—	0.28	0.11	0.09	−0.0004	−0.13	0.02	−0.01
Copper	0.28	—	−0.17	−0.07	0.003	−0.02	0.01	0.62
Manganese	0.11	−0.17	—	0.03	0.09	0.20	0.12	0.15
Gold	0.09	−0.07	0.03	—	0.16	0.01	−0.03	−0.12

Table III

Zinc, copper, manganese and gold contents in the hair of infants in dependence on age, ppm

Mean of age range	(in days)	1 (1—1)	83 (63—109)	224 (200—240)	402 (368—478)
Zinc	x̄ arithm	212	850	251	150
	s arithm	63 $p < 0.01$	341 $p < 0.01$	116 $p < 0.01$	84
	n number	41	12	14	20
	m median	193	780	221	137
	r range	145—456	354—1352	84—498	30—392
Copper	x̄	8.1	19.8	9.2	8.87
	s	2.3 $p<0.001$	13.4 $p<0.01$	2.3 $p>0.05$	4.01
	n	41	12	14	19
	m	7.6	14.9	8.8	8.6
	r	6.1—21.3	8.5—50.4	6.5—14.2	3.8—18.9
Manganese	x̄	0.21	0.25	0.47	0.29
	s	0.37 $p<0.01$	0.10 $p>0.05$	0.28 $p>0.05$	0.19
	n	32	6	13	11
	m	0.095	0.265	0.29	0.23
	r	0.04—1.42	0.11—0.38	0.08—1.00	0.04—0.61
Gold	x̄	0.009	0.142	0.118	0.038
	s	0.006	0.157	0.171	0.030
	n	41 $p < 0.001$	12 $p > 0.05$	14 $p < 0.01$	20
	m	0.007	0.081	0.068	0.035
	r	0.002—0.025	0.010—0.526	0.011—0.694	0.003—0.125

$p < 0.05$ = significant
$p > 0.05$ = non-significant

certainty (χ-test). Therefore, significance was calculated using the parameter-free Mann—Whitney or Kolmogorov—Smirnov-tests. Correlation was estimated by Spearman's rank correlation method.

Results

The zinc, copper, manganese and gold contents in the hair of newborn children are represented in Table I. There were no significant differences correlated with sex, so that the corresponding values may be averaged. The presentation of arithmetic means together with their deviations, medians as well as geometric means and their standard deviations is to facilitate comparison with relevant data by other authors.

Table II shows that in the case of normal newborn children no significant correlations were detected between birth weight, weight percentile according to Lubchenco et al [21], birth length, duration of pregnancy on the one hand, and the investigated trace element contents in the hair on the other hand. During the first three months of life a considerable increase in the zinc, copper and gold contents seemed to occur. According to our results, these changes were highly significant statistically (Table III).

During the first year of life the values decreased again to the initial levels or below them, but this fact has yet to be proven statistically (Table III, Fig. 1). Zinc, copper and gold showed significant positive correlations (Table IV). The same might be the case with copper and gold after a more extensive sampling. In the period between the 63th and the 478th day of life, zinc, copper and gold contents exhibited a significant negative correlation with age, body weight and length. In contrast to the other trace elements, the manganese contents in the hair of infants showed only slow changes during the first three months of life. A tendency to increase during the 4th to 6th months of life seemed to be conceivable and could be proved statistically, but it must be considered with some reservation because the

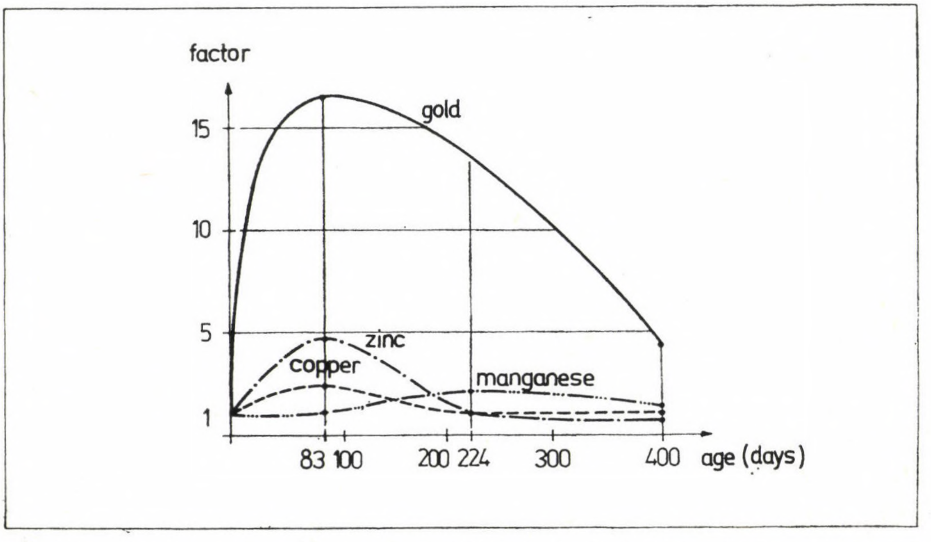

Fig. 1. Mean zinc, copper, manganese and gold contents in the hair of infants of increasing age as compared to the concentration at birth (= 1)

TABLE IV

Rank correlation coefficients between hair zinc, copper, manganese and gold contents of infants at age of 63–478 days and age, weight and length (n = 44; manganese values: n = 35)

	Zinc	Copper	Manganese	Gold	Age	Weight	Length
Zinc	—	0.50*	–0.20	0.55*	–0.74*	–0.72*	–0.78*
Copper	0.50*	—	–0.24	0.28	–0.57*	–0.51*	–0.45*
Manganese	–0.20	–0.24	—	0.01	0.21	0.26	0.17
Gold	0.55*	0.28	0.01	—	–0.52*	–0.43*	–0.54*

groups investigated were too small and because of the large standard deviation (Table III). Between the manganese content and the contents of the other trace elements in hair as well as parameters like age, body weight and length no significant correlations have been found within the period under examination (63th–478th day of life). Table IV illustrates this fact.

The variability of zinc, copper, manganese and gold contents in the hair of infants may be demonstrated in an impressive manner by relating the group means to the corresponding initial values of the newborn babies. Thus, the gold content showed a 15-fold increase on the average on the first 83 days of life (see Fig. 1).

DISCUSSION

The value of trace element analysis in hair for assessment of the individual trace element supply is on account of many known influences (contamination, speed of growth, high individual variations, unequal trace element distribution along the length of hair) considered by some authors to be positive [6, 17] and by others limited [10, 11] or negative [20, 22, 27].

Nevertheless, the physiological variations of trace elements in the hair of infants should be investigated by the present longitudinal observation. Our studies were in reasonably good agreement with mean values of other authors (Table V). The zinc content in the hair of newborn children resembled that of adults and of fetal bone tissue (149 ±3 ppm) [23]. In contrast, the zinc level in umbilical cord blood serum (0.83 ± ±0.12 μg/ml) and in amniotic fluid (0.304 ±0.104 μg/ml) [16] turned out to be amazingly low. According to the review of Bergmann et al [4] the zinc content decreases from 276 ppm (3rd month of life) to about 100 ppm (4th year of life) followed by a slow increase to the level of adults. The same tendency was observed by scanning babies and infants in Denver [4] and Bangkok [15] but the period of the first three months of life was neglected in these investigations. The massive increase in the hair zinc content obviously

TABLE V

Data in the literature concerning hair trace element contents of normal newborn children, ppm

	Zinc		Copper		Manganese		Gold	References
x̄ arithm	224.0		12.6		0.24		—	7
s arithm	6.29		0.61		0.04			Nova Scotia
	38		38		38			Canada
x̄ arithm	222.0		10.9				—	2
s arithm								Cincinnati
n								USA
x̄ arithm	174.0						—	15
s arithm	8.0							Denver
n								USA
x̄ arithm	235.2						—	5
s arithm	47.2							Frankfurt
n	30							FRG
x̄ arithm	Female	Male	Female	Male	Female	Male	—	29
	250	230	40	38	4.6	7.1		
s arithm	110	140	36	14	2.7	5.0		
n	17	24	14	17	16	19		Tokyo Japan
x̄ arithm			15					28
s arithm								
n			15					Dayton
								USA

precedes the above mentioned decay after the 3rd month and demonstrates the variability of the zinc content at early age. Moreover, the corresponding decrease of the mean serum zinc level from 0.77 ± 0.20 μg/ml at birth to 0.68 ± 0.09 μg/ml is noteworthy [8, 24].

Compared with the contents obtained by other authors, our hair copper values were low but they exhibited a similar temporal profile [9] (Table III, Fig. 1), although the analyses involved the whole length of hair while an unequal distribution of copper along the hair has been reported [11]. At the same time, the serum copper concentrations at birth were low and, in contrast to the serum zinc level, they rose continuously after birth [24] while the massive physiological copper depot in the liver was reduced.

Our values for the manganese contents in the hair of newborns agreed well with those obtained by Gibson et al [7], although our results showed a much wider scatter. The manganese and copper values for newborn children reported by Terai et al [29] from Japan are incomprehensibly high. Data by Gibson et al [9] showed an increase of manganese in infants' hair during the first three months of life. We found a slight rise of hair manganese content between the 200th and the 240th day of life which has been proven statistically. The relative steadiness of the hair manganese content compared with the other elements studied cannot be explained (Fig. 1) but might be in connection with the lack of a manganese-depot in the newborn infant [18].

Although gold is not considered to be an essential element, its biological effect is well-known e.g. in the therapy of rheumatism. Its physiological importance in healthy subjects has not been elucidated. The vehement increase by two orders of magnitude of the hair gold content during the first three months of life parallel to the increase of zinc and copper was an astonishing and new result of this study. Comparative data on hair gold content and dynamics in infants' hair could not be found; in adults the mean gold content of hair given in the literature amounts to 0.071 $\mu g/g$ [30].

The similar zinc, copper and manganese levels in hair found in different countries (Tables I and IV) suggest that even before birth there is some effective endogenous control or a genetic code of hair tissue composition. Eventual regional discrepancies could perhaps be explained by racial differences and/or environmental influences on the expectant woman. An innate lack of trace element supply in newborn children can hardly be verified by hair analysis, since even premature babies who are known to be insufficiently provided with trace elements, exhibit normal copper, zinc and manganese levels in the hair at birth [8]. In the case of infants, the steep increase of some hair trace element levels during the first three months after birth followed by a slow decrease may be interpreted in terms of adaptive, postnatal physiological regulations (hormonal adaptation, destruction of fetal red cells, loss of hepatic copper depot, etc.) as supported by the positive correlation between zinc, copper and gold dynamics (Table IV) and a similar increase of hair chromium values from birth to the third year of life [13].

Contamination of hair samples with copper, zinc and gold solely during the 63th to 109th days of life is not possible. Whether a diminished postnatal growth of hair or the change from newborn to infant hair in the first three months plays a role, must further be investigated.

Our results too, have shown, that a single hair trace element value without knowledge of its corresponding time dependence during early infancy cannot contribute to the description of the individual trace element supply. Extremes give little orientation. To what extent the individual hair trace element dynamics might be considered an apt criterion of the trace element status in early childhood, remains to be examined in detail.

References

1. Anke M, Risch M: Haaranalyse und Spurenelementstatus. Gustav Fischer, Jena 1979
2. Baumslag N, Yeager D, Levin L, Petering HG: Trace metal content of maternal and neonatal hair zinc, copper, iron, lead. Arch Environ Health 29: 186, 1974
3. Bencomo F, Amador M, Perez H, Conception M, Alvarez R, Padron M: Zinc concentration in plasma, erythrocyte and hair in supposedly healthy children. Rev Cub Pediatr 54: 425, 1982
4. Bergmann KE, Stegner W, Klarl A, Makosch G, Tews KH, Bergmann RL: Zinkmangel im Kindesalter. In: Spurenelemente-Analytik, Umsatz, Bedarf, Mangel und Toxikologie, eds Gladtke E, Heimann G, Eckert J, Thieme, Stuttgart 1979, p. 95
5. Bergmann KE, Makosch G, Tews KH: Abnormalities of hair zinc concentration in mothers of newborn infants with spina bifida. Am J Clin Nutr 33: 2145, 1980
6. Deming SB, Weber CW: Evaluation of hair analysis for determination of zinc status using rats. Am J Clin Nutr 31: 477, 1978
7. Gibson RS, de Wolfe MS: The zinc, copper, manganese, vanadium and iodine content of hair from 38 Canadian neonates. Pediatr Res 13: 959, 1979
8. Gibson RS, de Wolfe MS: Changes in serum zinc concentrations in some Canadian full-term and low birthweight infants from birth to six months. Acta Paediatr Scand 70: 497, 1981
9. Gibson RS, de Wolfe MS: Changes in hair trace metal concentrations of some Canadian low birth weight infants during the first six months of infancy. Nutr Rep Int 21: 341 1980
10. Hambidge KM: Hair analyses: worthless for vitamins, limited for minerals. Am J Clin Nutr 36: 943, 1982
11. Hambidge KM: Increase in hair copper concentration with increasing distance from the scalp. Am J Clin Nutr 26: 1212, 1973
12. Hambidge KM: The role of zinc deficiency in acrodermatitis enteropathica. Int J Dermatol 15: 38, 1976
13. Hambidge KM, Baum JD: Hair chromium concentrations of human newborn and during infancy. Am J Clin Nutr 25: 376, 1972
14. Hambidge KM, Hambidge C, Jacobs M, Baum JD: Low levels of zinc in hair, anorexia, poor growth, and hypogenesis in children. Pediatr Res 6: 868, 1972
15. Hambidge KM, Walravens PA: Zinc deficiency in infants and preadolescent children. In: Trace Elements in Human Health and Disease, ed Prasad AS, Academic Press, New York 1976, p. 21
16. Henkin RI, Marshall JR, Meret S: Maternal fetal metabolism of copper and zinc at term. Am J Obstet Gynecol 110: 131, 1971
17. Jacob RA, Klevay LM, Logan GM: Hair as a biopsy material V. Hair metal as an index of hepatic metal in rats: copper and zinc. Am J Clin Nutr 31: 477, 1978
18. Kirchgessner M, Weigand E, Schnegg A, Graßmann E, Schwarz FJ, Roth HP: Spurenelemente. In: Ernährungslehre und Diätetik, ed. Cremer HD, Hötzel D, Kühnau J Thieme, Stuttgart 1980, p. 275
19. Klevay LM: Hair as a biopsy material. I. Assessment of zinc nutriture. Am J Clin Nutr 23: 284, 1970
20. Klevay LM: Hair as a biopsy material. II. Assessment of copper nutriture. Am J Clin Nutr 23: 1194, 1970
21. Lubchenco LP, Hansmann C, Dressler M, Boyd E: Intrauterine growth as estimated from liveborn birthweight data at 24 to 42 weeks of gestation. Pediatrics 32: 793, 1963
22. McBean LD, Mahloudji M, Reinhold JG, Halsted JA: Correlation of zinc concentration in human plasma and hair. Am J Clin Nutr 24: 506, 1971
23. McIntosh N, Shaw JCL, Taghizadeh A: Direct evidence of calcium and trace mineral defects in the skeleton of preterm infants. Pediatr Res 8: 896, 1974
24. Ohtake M: Serum zinc and copper levels in healthy Japanese infants. Tohoku J Exp Med 123: 265, 1977
25. Ryabukhim YS: IAEA Report R 1: 50, 1978
26. Sandstead HH: Trace elements in medical practice: zinc. Pract Gastroent 2: 27, 1978
27. Solomons NW, Rosenberg IH, Sandstead HH, Vo-Khactu KP: Zinc deficiency in Crohn's disease. Digestion 16: 87, 1977
28. Strain WH, Lascari A, Pories W: Zinc deficiency in babies. In: Proc VII Int Congr Nutrition, ed: Kühnau J, Pergamon Press, Oxford 1966, p. 759
29. Terai M, Akabane A, Ohno K, Sakurai S, Tsunoda F, Hashimoto K, Nishida G: An application of neutron activation analysis to biological materials. II.

The comparison of trace element contents in normal and diseased infant hairs. J Radioanalyt Chem 52: 143, 1979
30. Wiesener W, Görner W, Niese S, Baldauf K, Grund W, Hennig M, Mende T: Neutronenaktivierungsanalytische Bestimmung von Spurenelementen im menschlichen Kopfhaar. Isotopenpraxis 17: 278, 1981

Received September 27, 1983

E Kauf MD
Universitäts-Kinderklinik
Kochstraße 2
DDR-6900 Jena, GDR