Hair and nails as bioindicators of Iron Levels in humans exposed to the metal in workplace

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Abstract :

The Iron levels in metal exposed male subjects in work place were determined. Biological tissues viz. biopsy materials of the exposed subjects relative to controls were taken as the biopsy material. Collection of samples, filling of questionnaire, washing and drying were done using recommended standard procedures. The water clear solution of the biological tissues was prepared by acid digestionusing HNO_3 and $HClO_4$ in (6:1ratio) in a Fume Hood Chamber. The analysis of the solutions was done on an Atomic Absorption Spectrophotometer Perkin Elmer Spectr Model AAS 4129. Fe levels exhibited enhancement with exposure which helps in ascertaining the intake of Fe by the exposed subjects. Influence of other factors on the levels of iron was also investigated. The results are confirmed by other biomonitoring studies performed using hair as biopsy material.

Key Words: Hair, nail, iron, workers, occupational exposure, atomic absorption spectrophotometer.

1.**Introduction**

Iron an abundantly available element .Average value of iron in human body is 4-5g.Iron is found in living cells due to its nutritive properties in trace quantities for the normal metabolism in organisms. The use of iron is of significance in powder metallurgy. In this is used in chemical applications serving as a catalyst. In addition it is also used as ingredient of cast iron and steel as also for ferrous and ferric salts. Steel alloys, dyes and abrasives are also made from Iron.

Absorption of Fe++ takes place in duodenum and upper jejunum. The combination of iron with the protein Apo ferritin, thus forming ferritin, takes place in the intestines .Ferritin is a storage compound.The iron store in the body and oxygen tension in the cells of intestine affect the absorption of iron. After iron enters the bloodstream, binding of iron and specific plasma protein, a Beta-Globulin, take place. Erythrocyte haemoglobincontain about 70% of the total iron. From the adult 1 mg iron is lost every day through biological fluids like urine and sweat, faecal matter, and biological tissues like hair. Since per day absorption of iron is 1 mg, the iron balance is maintained. Hair and nails are human biomarkers capable of giving continuous record of metals in humans.[1]-[4]

Iron deficiency anaemia is prevalent on a massive scale in malnourished infants and women in India. It may exhibit symptoms such as palpitation, persistent fatigue even on adequate rest, shortness of breath, muscular pain, dizziness, headache etc. In some cases, iron deficiency is also reported to let other metals absorb easily including cadmium and lead. Acute Fe toxicity can occur due to overdose of medicinal iron. Its symptoms include haemorrhagic gastritis, intravascular clotting, acidosis and fatal shock.

2.Experimental

In the present investigation, the male subjects working in workshops with iron as main metal were chosen along with age and sex matched controls. Biopsy materials viz. hair an nail was collected along with getting a questionnaire filled by each of them. The questionnaire contained details of personal characteristics such as age, type of work, food habit, smoking habit, place of residence and so on for further categorization. Scalp hair and finger nails were obtained using sterilized pair of scissorswashed with ethanol.All samples were stored in small bags in laboratory till they were analysed.

The biopsy materials were solubilised by first washing with deionized water, non-ionic detergent, acetone followed by final washing with deionized water and oven dried at 110^0C. Subsequently they were acid digested with digestion mixture of HNO_3 and $HClO_4$ keeping the ratio as 6:1. The residue was diluted with 0.1N Nitric Acid resulting in a clear solution for analysing it with a pre-calibrated Perkin Elmer Spectr Model AAS 4129 for determining the amount of Iron.Other techniques have been used as well [5] by other workers in the field.

Hollow cathode lamp used for iron was set at wavelength of 248.3nm. Lamp current was set as 5 mA along with 0.2nm spectral width. The prepared solutions were aspirated for determining the concentration of iron by AAS.

3.Results and Discussions

Table 1 Shows the Fe levels the sample solutions of different groups of ages from 11-20 to 51-60 years of age. As observed from the mean values, a definite increase or decrease in Fe levels is not seen. Eltayeb et al [6] have reported an initial increase in Fe levels with age groups followed by a decrease. Increase in Fe levels from children to adults are found by Moon et al [7] and also a decrease with age in adults. The high variation in Fe levels in a particular age group may amount to the observed Fe levels in the present study.

Table 1 Range and mean Iron levels (µg/g) in hair and finger nails of subjects of varying age groups

Age in years	No. of samples	Hair		Fingernails	
		Range(µg/g)	Mean± SD(µg/g)	Range(µg/g)	Mean± SD (µg/g)
11-20	47	33.11-679.32	150.60 (140.90)	31.21-618.69	303.03 (155.72)
21-30	77	12.66-823.85	137.50 (120.42)	36.65-601.90	262.41 (127-11)
31-40	71	15.16-827.91	150.43 (125.24)	37.96-600.12	322.62 (144.36)
41-50	79	31.64-335.68	129.25 (66.23)	25.33-601.22	251.65 (131.95)
51-60	66	32.42-413.37	155.25 (98.42)	31.17-474.90	262.35 (130.52)

Table 2 exhibits the different Fe levels in biopsy materials with respect to occupation of subjects. Significant't' test reveals that Fe levels is significant in hair samples of higher age group workers of locomotive workshops and metal finishing workshops as compared to other occupations , whereas these were significant in higher age group workers of automobile workshops, locomotive workshops and metal finishing workshops . The significant Fe concentrations in lower age group workers in finger nails in jewellery workers indicate that other factors also contribute towards the raised levels in these subjects. In a Study by Jamall et al 1987reports that measurement of plasma iron concentration, serum transferrin and total iron binding capacity, confirmed that the steel mill workers exposed to enhanced Fe levels in their environment are prone to adverse health effects. Literature reveals increased Fe levels in electroplating workers,welders, metallurgical workers and locomotive shed workers [8]-[12].Other work types on the contrary revealed low Fe levels in exposed subjects.

Table 2- Range and mean iron levels (µg/g) in hair and finger nails of subjects with different occupational exposure.

Subjects	Age in years	No. of samples	Hair		Fingernails	
			Range(µg/g)	Mean± SD(µg/g)	Range(µg/g)	Mean± SD (µg/g)
Control	11-30	22	30.12-681.32	154.36 (153.04)	34.61-61.71	338.87 (152.94)
Automobile Workshop	11-30	24	79.05-185.03	141.86 (31.82)	32.22 -355.45	188.00 (96.20)*
Locomotive Workshop	11-30	23	12.66-474.13	141.13 (88.12)	32.22-618.69	274.88 (152.10)*
Jewelry Manufacturing Units	11-30	26	33.11-823.85	136.50(139.97)	34.61-431.46	265.08 (99.71)*
Metal Finishing Workshops	11-30	29	48.13-820.90	164.21 (165.25)	31.21-588.53	319.02 (127.14)
Control	31-60	41	29.55-316.24	134.66 (69.94)	57.35-601.22	331.10 (161.05)
Automobile Workshop	31-60	43	30.65-336.69	140.98 (84.38)	34.61-600.12	235.99 (121.29)*
Locomotive Workshop	31-60	42	15.16-600.96	265.15 (145.04)*	25.33-256.02	124.15 (53.59)*
Jewelry Manufacturing Units	31-60	46	38.66-827.91	143.56 (89.76)	34.72-476.89	277.73 (126.68)
Metal Finishing Workshops	31-60	44	31.52-423.36	176.92 (107.77)*	32.22-462.85	239.88 (141.41)*

*Values significant at $P<0.05$ level

The classification of subjects and controls was done from 0-5 years as duration of exposure to 36-45 years as duration of exposure and the variation in the average Fe levels were investigated. Table 3 depicts the trend in levels of Fe in the selected sample materials. While an increasing trend with period of exposure is seen in fingernail samples with the Fe level values being statistically significant in 6-15 and 36-45 years age groups, the increase in Fe levels in hair samples is not somewhat continuous in the hair samples of these workers. However, significant values of Fe levels were obtained in hair of workers of 16-25 years duration of exposure.

Table 3- Range and mean iron levels (µg/g) in hair and finger nails of subjects with duration of exposure.

Duration of Exposure in years	No. of samples	Hair		Fingernails	
		Range(µg/g)	Mean± SD(µg/g)	Range (µg/g)	Mean± SD (µg/g)
Control	63	35.17-156.56	120.32 (103.23)	28.54-321.33	250.11 (178.23)
0-5	35	68.90-509.25	170.85 (124.38)*	25.33-459.23	268.44 (182.78)
6-15	61	30.12-681.32	143.90 (140.28)	56.34-618.69	318.04 (143.55)*
16-25	64	30.12-827.91	173.46 (158.85)*	51.31-600.91	268.45 (142.50)
26-35	58	12.66-239.91	110.00 (62.45)	32.22-431.46	270.07 (109.18)
36-45	59	29.55-826.90	165.84 (164.30)	57.35-588.53	311.32 (126.57)*

*Values significant at P<0.05 level

Range and mean Fe levels dependence on hair colour in the age groups studied are shown in Table 4. The table evinces decrease of Fe in black hair with age in general in Black and Brown Hair colour. In mixed hair colour a high Fe level is observed in 31-40 years age group which is not in line with the decreasing values. Grey hair colour samples showed a decrease in 31-40 years age group from 21-30 years followed by an increase. Significant Fe concentration in mixed hair and grey hair of subjects of 21-30 years was observed as a result of test of significance. High Fe concentration in grey hair of 51-60 years does not confirm the usual behaviour showing association of depigmentation with low Fe content. [13]-[14].

Table 4- Range and mean Iron levels (μg/g) in hair of subjects of varying age groups as a function of hair colour.

Subjects	Age in years	No. of samples	Hair	
			Range(μg/g)	Mean± SD(μg/g)
Black	11-20	26	49.56-507.23	162.76 (107.12)
Brown	11-20	9	33.11-456.55	162.05 (133.82)
Mixed	11-20	11	39.35-679.32	130.25 (174.77)
Grey	11-20	1	69.12	-
Black	21-30	36	32.40-455.62	140.16 (85.73)
Brown	21-30	5	12.66-230.83	140.34 (78.71)
Mixed	21-30	32	16.69-202.21	94.47 (56.02)*
Grey	21-30	4	87.17-823.85	269.52 (280.91)*
Black	31-40	26	35.80-280.53	144.92 (61.90)
Brown	31-40	8	15.16-314.22	144.25 (102.06)
Mixed	31-40	28	27.30-827.91	174.85 (204.36)
Grey	31-40	9	49.12-172.62	104.44 (46.43)
Black	41-50	24	31.64-279.11	139.67 (63.62)
Brown	41-50	9	34.66-170.56	103.67 (40.97)
Mixed	41-50	36	33.99-260.33	138.19 (66.45)
Grey	41-50	10	44.25-335.68	137.96 (95.50)
Black	51-60	13	49.33-393.27	143.80 (92.19)
Brown	51-60	9	40.53-279.40	152.79 (74.04)
Mixed	51-60	31	36.67-413.37	158.96 (102.48)
Grey	51-60	13	32.42-390.52	169.92 (111.34)

*Values significant at $P < 0.05$ level

Table 5 reports the mean Fe Levels in hair and nails of healthy subjects and subjects with disease. Fe was significant in subjects with hypertension, reproductive disorder and respiratory problem using hair as biopsy material whereas in nail biopsy materials Fe levels were insignificant .Studies are missing on correlation of Fe content and diseases [15].Fe levels were insignificant in subjects with disease other than these.

Table 5- Range and mean Iron levels (µg/g) in hair and finger nails of subject with health disorders and their respective controls.

Subjects	No. of samples	Hair		Fingernails	
		Range(µg/g)	Mean± SD(µg/g)	Range(µg/g)	Mean± SD (µg/g)
Controls	44	27.33-679.33	155.92 (127.89)	31.21-618.69	271.20 (136.66)
Acidity	39	35.90-820.87	170.41 (142.80)	57.35-475.90	271.07(120.62)
Diabetes	34	17.12-507.24	202.32(130.35)	35.62-593.4	261.47(137.65)
Hypertension	32	12.66-259.03	92.26(54.98)*	33.62-601.97	276.59 (150.22)
Hypotension	36	13.63-316.24	113.34 (68.52)	34.61-600.91	279.91 (147.50)
Mental Stress	43	28.84-378.55	132.13(74.02)	25.33-616.13	264.18(144.56)
Reproductive Disorder	23	14.78-183.82	111.33(58.62)*	126.36-601.92	300.61 (123.95)
Respiratory Problem	46	16.84-256.98	114.62(56.34)*	123.84-602.90	309.76(132.12)
Skin Disease	43	28.56-827.91	171.93(147.69)	31.23-601.92	282.69(166.28)

*Values significant at $P<0.05$ level

In an overall conclusion Iron levels as analysed using biological tissues as biopsy materials in the Fe exposed subjects with age and sex matched controls, reveal its significant concentrations in workers exposed in their workplace with respect to some work types like automobile workshops, locomotive workshops and metal finishing workshops particularly in higher age groups. Necessary preventive measures viz. masks and gloves are necessitated as also it leads on to infer that hair and nails can be used as bioindicators for iron.

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