Hardness of human nail as an index of nutritional status: a preliminary communication

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1. The Knoop test of hardness of materials has been used to test the hardness of human nail.

2. The range of hardness of nails was found to be small in healthy persons and large in malnourished children.

3. Nails from malnourished children were in general much harder than those from healthy persons. The nails of a small group of three children became softer while they were recovering from malnutrition.

Objective indices of nutritional status are few. Anthropometric measurements which are commonly used to evaluate growth may reflect factors other than nutrition. The measurement of nutrient concentrations in body tissues and fluids is helpful in evaluating whether malnutrition exists, but it does not necessarily ascertain the extent nor define the magnitude of nutritional disease (WHO, 1963). Biophysical tests have been limited mainly to radiographic examination and to tests of alteration of function (Jelliffe, 1966); however, the physical character of the integuments of the body may reflect recent nutritional status. Gilchrist & Buxton (1935) observed, for example, that the nails of poorly nourished children grew more slowly. The chemical composition and structure of human nails is also known to alter in disease states (Sibinga, 1959), the calcium content increasing in protein-calorie malnutrition (Leonard, Morris & Brown, 1968). As the composition and structure of nail alters, changes must be expected in its physical characteristics.

Hardness of nail is a physical characteristic that can be easily measured. This paper describes a technique for measuring hardness and the results obtained from testing nail clippings collected from well-nourished and malnourished individuals.

EXPERIMENTAL

The sample

Finger nails were collected from two sources. The first was a group of thirty-five apparently healthy and adequately nourished adults, infants, and children. A subject was considered healthy and adequately nourished if there were no overt signs of disease or nutritional deficiency, nor a history of illness, injury or infection, during the previous 6 weeks and if the subject was neither underweight nor more than 20% overweight, according to the criteria in the *Metropolitan Life Tables Build and Blood Pressure Study* (Society of Actuaries, 1959). The second source was a group of nineteen Filipino and three Puerto Rican infants and children suffering from severe protein-calorie malnutrition of the kwashiorkor type. All were oedematous on admission to hospital; they were underweight and stunted compared with 'normal' children of the same age from the same geographical location.

Method

The Knoop test of hardness of materials, widely used in industry, was applied to human nails.

Finger nail clippings at least 2 mm × 4 mm in size were embedded in a block of cold-setting polyester resin (Polyester Resin 207 D and MEK Hardener; Tool Chemical Co., Inc., Hazel Park, Michigan, USA). The block with the dorsal surface of the nail uppermost was then polished by wet grinding on a rotary cap through a series of silicon carbide papers finishing at 600 mesh grit. Final polishing was accomplished on a vibratory polisher in an aqueous solution of Linde 'B' alumina (Kehl, 1949). It was inevitable that some of the natural curvature of the nail was retained during the embedding process; consequently, the polished surface of the nail represented varying levels of the nail structure. It was estimated, however, that the surface produced by polishing and used for measurement was never more than 0·01 mm from the original nail surface. The hardness of the nails was measured by an identation test of the polished surfaces. This test technique involved the application of a load to a Knoop diamond indentor mounted in a Tukon Hardness Tester (Model MO, manufactured by the Wilson Mechanical Instrument Division of the American Chain and Cable Co., Inc., New York). Loads of 25–100 g depending on the hardness of the nail were used and were applied at a constant rate for 3 s. The long diagonal (d) of the indentation was then measured with the optical grid of a Filar eyepiece. The reticle of this eyepiece consists of a fixed micrometer scale ruled at intervals of 0·5 mm, a vertical hairline that can be moved across the field of view by means of a micrometer screw, and a fixed horizontal hairline. Measurements can be made to 0·001 mm (Kehl, 1949). No change occurred in the long diagonal after intervals of 1 min, 1 h and 1 d. The length of the indentation, which is dependent on the hardness of the material, was then converted into Knoop hardness number (KHN) using the formula:

$$\text{KHN} = \frac{\text{load}}{\text{area}} = \frac{L}{d^2 C_p},$$

where load is expressed in kg, C_p is a constant relating the longer diagonal to the unrecovered area = 0·07028, and d = length in mm of the longer diagonal.

Initially, samples for testing were taken from each finger of both hands of three healthy adults. After polishing, the hardness of each nail was measured at its proximal and distal edges and midway between, as well as over the medial, lateral and intermediate aspects of the nail. An analysis of variance of the results revealed that, in each subject, the variance of hardness of each nail at these sites was less than the variance of hardness of nails of different fingers. In the remainder of the tests, three indentations were made randomly on each polished nail taken from the middle finger of the left hand. This site was selected somewhat arbitrarily. However, this finger is rarely sucked by children and therefore less likely to be softened.

In the polishing process, the nail was exposed to an aqueous solution which could have softened it. If this was so, it would be expected that hardness would have increased if the specimen had been allowed to stand in a dry atmosphere. However, test results showed that for nails kept in desiccators no significant differences in KHN were observed after 3 d. Preliminary tests on nails had established that measurements made at three successively deeper levels in the nail did not vary significantly unless the indentor was penetrating the nail.

RESULTS AND DISCUSSION

The results showed differences in nail hardness between malnourished and well-nourished children (Table 1). The mean hardness for the well-nourished group was lower than that for the malnourished group. The range of hardness of nails from the

Table 1. *Nail hardness in well-nourished and malnourished individuals*

Status	Age (years)	Race	No. of individuals	Knoop hardness number Mean	SD	Range
Well-nourished	All ages	All	35	24·25	3·48	14·0– 44·1
Well-nourished	0–7	All	14	22·16	3·27	14·0– 27·5
Malnourished	0–7	Puerto Rican	3	32·21	8·16	21·3– 42·0
Malnourished	0–7	Filipino	19	34·38	29·97	16·5–145·0
Malnourished	0–7	All	22	34·09	27·98	16·5–145·0

Table 2. *Change in nail hardness during recovery from protein-calorie malnutrition*

Subject no.	Knoop hardness number (see p. 234) On 15. v. 70	On 5. vi. 70
1	24·9	21·6
2	25·5	23·3
3	61·8	18·8

healthy group was small, whereas that for the malnourished group was large. The highest KHN values were observed in a 2-year-old Filipino child suffering from severe protein-calorie malnutrition of several months duration who had just been admitted to hospital.

Hardness tests conducted on nails of three malnourished children at an interval of 3 weeks during convalescence showed a reduction in the KHN during this period of time (Table 2). In view of the relatively short period of time which elapsed between the two examinations, it is difficult to believe that the structure could have changed so dramatically as a result of improved nutritional status. No other data are available to show changes in nail hardness in the same individual over a period of time. Measurement of hardness in serial samples of nail clippings may provide further information on changes in nail hardness in healthy subjects and in patients recovering from malnutrition.

CONCLUSIONS

The Knoop hardness test can be applied to human nails. In healthy well-nourished individuals, the range of hardness is small; in malnourished individuals, nails are harder and the range is greater. No explanation is offered for these observed differences. Before hardness of nail can be considered an index of nutritional status, further studies should be made of changes in hardness in healthy, sick, and malnourished individuals.

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