Hardness of finger nails in well-nourished and malnourished populations

By J. R. K. ROBSON

Nutrition Program, School of Public Health, The University of Michigan, Ann Arbor, Michigan 48104, *USA*

(*Received* 26 *November* 1973 – *Accepted* 4 *February* 1974)

1. The Knoop test of hardness applied to samples of finger nails from 334 healthy and 147 malnourished individuals showed statistically significant differences in the mean hardness of the nails of the two groups.

2. The hardest nails were those of Filipino infants and children suffering from protein-energy deficiency. The softest nails were those of children in Guatemala recovering from protein-energy deficiency. Ranking of hardness appeared to be related to the severity and duration of protein-energy depletion.

3. In children up to 12 years of age, hardness did not appear to be influenced by the age, sex, and racial origins of individuals or the environmental conditions to which nail specimens were exposed.

4. Further studies are required to correlate hardness with clinical, biochemical and anthropometric measurements of nutritional status during protein-energy deprivation and during recovery. The causes of the differences in hardness need to be explored.

The chemical composition and structure of human nails is known to alter both in disease and malnutrition (Sibinga, 1959; Leonard, Morris & Brown, 1968). As a result, changes might be expected in the physical characteristics of this integument.

The Knoop test of hardness has been used to test the hardness of human nail. In a preliminary study the range of hardness values was found to be small in healthy infants, children and adults. In malnourished children the range was large and in general the nails were harder than those from healthy persons (Robson & El Tahawi, 1971).

The Knoop hardness test has now been applied to a larger sample of nails from two groups representing well-nourished and malnourished populations.

EXPERIMENTAL

The sample

Samples were grouped into two categories. The first category comprised nails collected from 334 children of European and Negroid origins; this sample was designated 'normal'. The physical appearance of all of these children was apparently healthy and they were considered to be well-nourished. All of them were regularly attending an elementary school in the Ypsilanti School District of Washtenaw County, Michigan. Any child with growth disturbance (including obesity), a current health problem, or an illness within 6 weeks prior to the examination, serious enough for him to miss school, was excluded from the study. All of the subjects were above the 3rd

Table 1. *Characteristics of subjects providing samples of finger-nail clippings*

Group	Subgroup	No.	Age range	Characteristics
Normal	—	334	5–12 years	Apparently healthy, well-nourished, above 3rd percentile for height and weight. Caucasian and Negroid origins.
Malnourished	Failure to thrive	20	5 months–7 years	Failure to achieve 3rd percentile for height and weight. No obvious pathology present, and adequate diet available. Clinical diagnosis of 'failure to thrive'. Caucasians and Negroids.
	Acute illness	9	1 month–5 years	Suffering from acute illness, hospitalized for treatment. Clinical diagnosis included viral pneumonia, acute otitis media, pyrexia of unknown origin. Caucasians and Negroids.
	Phenylketonuria	54	5 days–7 years	Confirmed diagnosis of phenylketonuria. All cases under dietary treatment. Caucasians.
	Kwashiorkor (recovery)	18	15 months–7 years	Kwashiorkor diagnosed. All cases under treatment were in recovery stage and in care of Rehabilitation Centre in Guatemala.
	Kwashiorkor and marasmus	30	11 months–6 years	Fifteen diagnosed as kwashiorkor, fifteen as marasmus. All Filipinos admitted to hospital. Samples taken on admission.
	Secondary malnutrition	16	Adults	Suffering from malnutrition secondary to malabsorption syndrome. Caucasians.

percentile for height and weight as judged by the Iowa Standards (Stuart & Meredith, 1946). Their ages ranged between 5 and 12 years.

The second sample, designated 'malnourished', comprised nails collected from 131 infants and children suffering from a variety of conditions which were judged to have affected their nutritional status. The sample included nails from eighteen children recovering from kwashiorkor in rehabilitation centres in the city of Guatemala. It also included specimens from thirty cases of marasmus and kwashiorkor admitted to the National Children's Hospital, Quezon City, Philippines. There were also nails from children diagnosed as 'failure to thrive' in the Washtenaw County Well Baby Clinic at Ypsilanti, Michigan. Children acutely ill in Detroit General Hospital were used as a source for the nails in the subgroup designated 'acute illness'. The cases of phenylketonuria were from various locations in Michigan, but they were all under surveillance in the University Hospital. Also included in this group were nails from sixteen adults suffering from secondary malnutrition. The characteristics of the subjects providing samples of nails to the two groups are shown in Table 1.

Method

All specimens had been removed from the left middle finger by either nail clippers or scissors. Specimens from overseas were placed in small paper envelopes and immediately airmailed to the laboratory. On receipt, all these specimens and those

Table 2. *Knoop hardness numbers for finger nails* from groups of normal and malnourished individuals. Malnourished subgroups are ranked in order of hardness*

Sample	No. in sample	Mean hardness	SD	SE	Range
All nails	497	18·44	5·27	0·23	5·40–95·60
All normals	334	17·80	4·46	0·24	5·40–63·10
All malnourished	147	19·01	5·41	0·44	7·66–95·60
Kwashiorkor (recovery)	18	13·59	2·22	0·52	10·73–18·80
Acute illness	9	13·63	3·87	1·29	7·66–18·90
Secondary malnutrition	16	17·39	4·34	1·08	11·76–24·90
Phenylketonuria	54	18·79	3·88	0·52	10·13–25·33
Failure to thrive	20	20·74	3·83	0·85	13·36–29·40
Marasmus	15	22·06	2·60	0·67	17·90–27·96
Kwashiorkor	15	25·83	7·94	2·05	16·43–95·60

* Robson & El Tahawi (1971).

collected locally were mounted in phenolic resin. The embedded nails were polished and subjected to the Knoop test of hardness of materials as described previously (Robson & El Tahawi, 1971). Three hardness readings were taken at different sites on each nail clipping, and they were converted to Knoop hardness numbers from a standard conversion table after each measuring session.

Statistical analysis

The results were coded and punched onto IBM punch cards and processed by the MIDAS (Michigan Interactive Data Analysis System) computer program. The results were treated as a whole and by subgroups. A one-way analysis of variance was applied to test the hypothesis that the group means were equal. Two-sided comparisons were made using Dunnett's procedure (Steel & Torrie, 1960).

RESULTS AND DISCUSSION

The means, standard deviations, standard errors of the means, and ranges of hardness of the groups and subgroups are shown in Table 2. Differences in the mean Knoop hardness numbers of nails from the normal and malnourished groups were significant ($P < 0{\cdot}01$).

The mean hardness of the normals was compared with each of the malnourished subgroups. The hypothesis that the normal and subgroup means were equal was rejected in favour of the alternative of unequal means ($F_{7473} = 13{\cdot}752$, $P < 0{\cdot}0005$). Dunnett's procedure provides for paired comparisons (normals *v.* malnourished groups). Seven comparisons were made at an over-all level of significance of 5% ($\alpha = 0{\cdot}05$). Significant differences were found between the means of hardness for the normal group and the malnourished subgroups designated 'failure to thrive', 'kwashiorkor (recovery)', 'acute illness', 'kwashiorkor', and 'marasmus'. There were no significant differences between the normal group and the malnourished subgroups designated 'secondary malnutrition' and 'phenylketonuria' (see Table 3).

The observed differences could have been due to a number of factors. First, consideration has to be given to variations inherent in the methodology. Thus, variability

Table 3. *Significance of difference in means of hardness of nails from normal and malnourished subgroups*

Comparison of normal *v.*:	Difference ($\bar{x}-\bar{x}$ normal)	Dunnett allowance (0·5)*	Significance
Failure to thrive	2·9659	2·7585	+
Kwashiorkor (recovery)	−4·1916	2·7956	+
Secondary malnutrition	−0·38537	2·9556	−
Phenylketonuria	1·0068	1·6934	−
Acute illness	−4·1462	3·9009	+
Marasmus	4·2789	3·0490	+
Kwashiorkor	8·0545	3·0490	+

* If the mean difference exceeds ± the Dunnett allowance, the difference is declared significant.

in the hardness-testing machine, variations in the technique, and errors in computing the hardness numbers could influence the results. In view of the large numbers in the sample, the reliability of the test, the known accuracy of the hardness-testing machine and the experience of the technician, these factors were not considered to be responsible for the observed differences. Another possible extrinsic influence on nail hardness was the effect of the environment over the passage of time.

Twenty nails from the normal group selected at random were examined twice at an interval of 10 months. Differences in hardness did not, in any sample, exceed the range of hardness found in multiple measurements on a single nail. Two other possible causes of the differences in hardness were considered. First, there were differences in the age structure of the subjects in the malnourished and normal groups. The effect of age on hardness was assessed from frequency distribution diagrams plotting age against hardness for all samples from subjects under 12 years of age (normal and malnourished) and normal subjects under 12 years of age. The distribution of the plots was random and did not suggest any relationship between hardness, or softness, and age up to 12 years of age. It is possible that, after puberty, sex differences and occupational and degenerative effects are likely to influence hardness.

The effect of different environments on the hardness of normal nails has not been evaluated. All the normal nails were collected in the temperate midwestern United States, whereas all the hard nails were from children suffering from kwashiorkor or marasmus in the tropics. The soft nails of children recovering from kwashiorkor suggests that location did not determine hardness. Differences in hardness attributable to the varying racial and sex structure of the individuals supplying the samples could not be completely discounted since no samples were measured from 'normal' Filipino or Guatemalan Indian children. But, when the mean hardness of samples from males and females and from Blacks and Caucasians were compared, no significant differences in hardness were found between the two sexes and the two ethnic groups.

The ranking of mean hardness suggests that this property is related to the duration and severity of protein or energy deprivation, or both. Thus, the hardest nails were found in children with kwashiorkor and marasmus; there was no statistical difference

Table 4. *Changes in nail hardness during recovery from disease*

Case	Diagnosis	Sex	Date	Hardness*	Body-wt (kg)
A	'Short bowel'	♂	Sept. 1971	20·8	54·7
			Nov. 1971	21·6	—
			Mar. 1972	12·4	—
			May 1972	13·8	—
			July 1972	13·4	63·1
B	'Nontropical sprue'	♀	Sept 1971	20·0	35·8
			Nov. 1971	12·8	35·8

* Knoop hardness number (Robson & El Tahawi, 1971).

in the means of hardness numbers to suggest a possible method of differentiating these two forms of protein malnutrition. The softest nails were those of Guatemalan children recovering from kwashiorkor. All of these children had been given adequate amounts of good-quality protein during rehabilitation. It has been noted previously that nails became softer during recovery (Robson & El Tahawi, 1971); these results show that the nails of the recovering Guatemalan children were significantly softer than normal. The mean hardness of the remaining subgroups, namely those suffering from phenylketonuria and chronic disease, was not significantly different from the means of the normal group. The numbers in the acute illness group were very small, however, and this sample may not be representative. Furthermore, the children with acute illness were all from a very poor part of Detroit where undernutrition is known to exist. All of the children with phenylketonuria had been under the care of a specialized unit and they were under dietary control, making satisfactory clinical progress.

The cases in the chronic disease category were also under treatment. One of these was an adult male with malnutrition secondary to a surgically-induced short bowel. Over a period of 8 months his weight increased from 54·7 to 63·1 kg. A second subject in this group was a 35·8 kg adult female with nontropical sprue who showed a marked clinical improvement over a period of 2 months. The increasing softness of the nails of these two subjects is shown in Table 4. No trends in hardness were observed in nine subjects with phenylketonuria whose nails were examined every 4 weeks over a period of 12 weeks.

The mean hardness of the malnourished group was lower than the values previously reported by Robson & El Tahawi (1971). In the earlier study the mean values for hardness in groups of malnourished infants and children were 32·21, 34·48 and 34·09 respectively. The mean for 147 samples from the malnourished group in the present study was weighted by low values from the Guatemalan children recovering from malnutrition, as well as others whose clinical condition was not serious. The lower values could have been due also to the use, in all instances, of the 25 g stylus impression weight. In the earlier study stylus weights varying between 25 g and 100 g had been used.

In conclusion, statistically significant differences were noted in the hardness of samples of finger nails from normal and malnourished groups. The hardest nails were found in Filipino infants and children, the softest nails were found in Guatemalan

children recovering from kwashiorkor. The results support the hypothesis that up to 12 years of age at least, hardness of nail is an index of nutritional status, but further investigations are required to correlate nail hardness with clinical, anthropometric and biochemical measurements in subjects with protein-energy deficiency. These subjects should be selected from different environments and comparisons should be made during the acute stages of the disease and in recovery.

Further study is required also to determine the cause of the differences observed. Mineral deficiencies including those of iron and zinc may have co-existed with malnutrition suggesting the need for chemical examination of nails in health and disease.

This study could not have been possible without the help of a number of colleagues and I wish to express my appreciation to them. They include Dr Ivan Beghin of the Institute of Nutrition for Central America and Panama for his help in providing specimens from Guatemala, and Dr Crisanta de Joya-Agregado, who provided specimens from patients in the National Children's Hospital, Quezon City, Philippines. Dr A. B. French and Dr R. J. Allen kindly arranged for the periodic collection of specimens from their patients in the University Hospital. The Tukon hardness tester was made available by Professor W. C. Bigelow of the Department of Materials and Metallurgical Engineering, College of Engineering. Mr George Brooks of the same department devoted much of his own time to supervising the measurement of the specimens. Mr James Bursick of the Department of Biostatistics, School of Public Health assisted in the statistical testing of the results. The research was supported by Contract No. HSM 21-71-535, Department of Health, Education and Welfare, Center for Disease Control, Atlanta, Georgia.

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Printed in Great Britain