INTERCORRELATION STUDY OF DIETARY AND BIOCHEMICAL DATA FROM SCHOOLCHILDREN IN THE PRETORIA AREA*

M. E. J. LOUW AND J. P. DU PLESSIS, *National Nutrition Research Institute, CSIR, Pretoria;* A. S. VAN DEN BERG, *Department of Home Economics and Dietetics, University of Pretoria;* AND S. A. FELLINGHAM, *National Research Institute for Mathematical Sciences, CSIR, Pretoria*

While a number of studies of the dietary intake, growth and health of children have been carried out in this country,[1-6] none have been published of concurrently collected dietary, physical and/or biochemical data or of the interrelationships between these findings.

This study comprises an evaluation of relationships between the dietary and biochemical data of a nutrition survey carried out during the period 1962 - 1965 on 1,963 children from the 4 main racial groups in Pretoria. Information on the biochemical and dietary methods used and the biochemical results have already been published.[7-9] The only dietary results so far published are those in respect of the 7-year-old White children.[9]

In the assessment of nutrition status, the interpretation of both dietary and biochemical data and their interrelationships presents many problems.

PROBLEMS ENCOUNTERED

Problems in the Interpretation of Dietary Data

Many factors complicate the evaluation of dietary adequacy. Although the minimal intakes required to prevent signs of deficiency can be determined under set experimental conditions, current knowledge is not sufficient to allow a complete statement to be made of the nutrient needs of an individual under everyday living conditions. Data on nutrient requirements are limited and their interpretation is controversial for several reasons:

(*a*) There are marked intra- and interindividual variations in requirements. Factors affecting requirements may be classified as relating to agent, host or environment.[10] Agent factors include (*i*) nutrient precursors, e.g. carotenes, which have to be converted into active nutrients by the body; and (*ii*) the availability of nutrients in food, e.g. the nicotinic acid in maize which, in bound form, is largely unavailable to man. Host factors—e.g. activity, genetic variability and pathological state—influence individual and daily requirements. Environmental factors which may influence requirements include temperature, humidity and the amount of sunlight available daily.

(*b*) Methods for determining requirements are neither simple nor fool-proof; e.g. the results of calcium balance studies may be influenced by the previous habitual calcium intake of the experimental subjects.[11]

(*c*) Uncertainty exists regarding criteria of deficiency or adequacy. The problem of defining optimum nutrition and optimum health has not yet been solved.[12,13]

A diet can be tested against a dietary standard to obtain some measure of its comparative adequacy. However, since dietary standards are arbitrary in many respects (because of limited information on nutrient requirements and also because of differences in approach to their formulation),[14,15] there are marked differences between the nutrient allowances recommended by different authorities. Differences in the assessment of dietary adequacy would therefore arise according to the standard used. In the Pretoria survey, the dietary data for the 7-year-old White children have been compared with the 1956 South African,[15] and the 1963 American[14] recommendations respectively, and illustrate the difference in results that can be obtained by using different tables; for example, when the South African tables were used, 8% of the 7-year-old White children had a vitamin-C intake of less than 50% of the recommended allowance, but when the American tables were used, the vitamin-C intakes of 27% of these children were below 50% of the recommended intake. Recently Leverton[16] drew attention to the difference that revisions of a particular standard can make in the assessment of the adequacy of a diet.

Problems in Interpreting Biochemical Data

As in the case of dietary data, caution must be exercised in the interpretation of biochemical findings in terms of adequate nutrition or deficiency. Biochemical tests have not been studied sufficiently under different conditions and at various levels of nutrition to make precise interpretation possible, especially in children, nor have the concepts of adequate nutrition, potential deficiency, or optimum nutrition been clearly delineated. Variations in biochemical findings, for example, in the levels of circulating blood components, may reflect the effect of factors other than nutrient intake, such as interrelationships between biochemical parameters, sex, age, race and disease.

The influence of biochemical interrelationships on biochemical results is well illustrated by serum vitamin-A and protein values. Serum vitamin A is transported as part of a protein complex,[17,18] and protein deficiency may therefore be a cause of low serum vitamin-A levels. In conjunction with an increase in serum albumin values, Arroyave *et al.*[19] observed a rise in serum vitamin A levels in treated kwashiorkor patients, although no supplementary vitamin A had been given to these patients.

Age has an important influence on some biochemical findings, for example on urinary thiamine excretion,[7] while other parameters such as urinary urea excretions are influenced by both age and sex.[7]

Differences in biochemical data found between racial groups may be genetic or environmental in origin;[20] for example, the high γ-globulin values reported for South African Bantu,[7] healthy Nigerians[21] and United States Negroes[22,23] could be a racial characteristic, or could be the result of external factors such as exposure to infections. The study carried out by Antonis and Bersohn[24] on White and Bantu prisoners, which showed that the serum lipids of both groups reacted in the same way to changes in the dietary intake of carbohydrate and fa

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indicate that the reported differences in serum cholesterol values between different races might be due to dietary and not to racial factors.

Many biochemical parameters are influenced by disease; for example, an increase in serum γ-globulin values has been reported in parasitic infection[26] and in liver disorders.[27]

Problems in the Evaluation of the Relationship between Dietary and Biochemical Data

The relationships between dietary and biochemical data have often been studied by changing the intake level of only one nutrient in an otherwise constant diet.[28-32] The relationships found under such experimental conditions are not always borne out by the results of nutrition surveys conducted under ordinary living conditions; for example, Donald *et al.*[33] reported excellent vitamin-A nutrition in Washington adolescents when judged by dietary intake data, while clinical and biochemical findings for the same children indicated only fair to good vitamin-A nutrition. The limitations of methods used to collect and evaluate both dietary and biochemical data that may influence the correlation between these parameters include the following:

(*a*) Dietary data may reflect the habitual food intake or the intake during a specific period, e.g. 24 hours, while biochemical data may reflect the current dietary intake and/or the storage of nutrients; for example, it has been reported that, with adequate stores of vitamin A, serum levels remain fairly constant in spite of varying intake, and only when reserves are depleted (which may take months on a vitamin-A-free diet) will a low dietary intake be reflected by a substantial drop in serum values.[34]

(*b*) The interrelationship between nutrients makes the evaluation of dietary data very difficult; for example, thiamine requirements are related both to carbohydrate and to total calorie consumption.

(*c*) The biological availability of nutrients may vary; for example, the nicotinic acid in maize exists largely in a bound form not available for utilization by man.[35] Many non-Whites, despite their high intake of nicotinic acid from maize, still show nicotinic acid deficiencies.

(*d*) There are problems in the interpretation of the relationships between dietary and biochemical data at different levels of nutrition status. For example, studies have shown that, when the dietary intake of certain nutrients such as thiamine or riboflavin is high, there are wide variations in the amounts excreted by different people, and from day to day. As intakes decrease, these variations become smaller; at low levels of intake (i.e. below minimum requirements) a linear relationship exists between urinary excretion and dietary intake.[28,36]

(*e*) When differences in nutrition status between individuals are small, the influence of intra- and interindividual variations in biochemical values and inaccuracies in dietary data make it difficult, if not impossible, to establish correlations between dietary and biochemical findings. The use of homogeneous groups in nutrition survey studies may, for example, be partly responsible for the low correlation found when relating individual serum cholesterol values to the habitual dietary intake of calories, fat, protein and carbohydrate.[37-41]

In view of the many problems relating to the interpretation of both dietary and biochemical data, extreme caution is necessary to ensure that valid conclusions are drawn regarding nutrition status. The present study was undertaken to determine correlations between the dietary and biochemical data of a nutrition survey conducted on Pretoria schoolchildren from 4 racial groups with marked differences in dietary habits and nutrition status.[7,8,42] Such a correlation study can contribute to a more meaningful interpretation of dietary and biochemical data in the evaluation of nutrition status, and can also assist in the appraisal of the suitability of the evaluation methods used. Since closer correlations between the different findings in a nutrition survey might be expected in a heterogeneous than in a homogeneous group, the biochemical and dietary findings on the 4 racial groups were pooled for evaluation purposes.

MATERIALS AND METHODS

During the period 1962 - 1965 the National Nutrition Research Institute (NNRI) of the CSIR carried out extensive nutrition surveys on White, Bantu, Coloured and Indian schoolchildren in the Pretoria area. Each survey included dietary, biochemical, clinical, haematological and socio-economic investigations. The dietary surveys and the collection of blood and urine samples for the biochemical analyses were carried out by the Division of Field Studies of the NNRI, while the Division of Physiological Chemistry of the same Institute was responsible for the biochemical determinations. All the children for whom both biochemical and dietary data were available have been included in the present study. Details of age and racial distribution are given in Table I.

The geographical area involved and the statistical planning of the surveys have already been described in detail,[43] and the execution of the programme has been described by Van der Merwe *et al.*[42] Details of the biochemical assays carried out in the Pretoria nutrition surveys, assessment of their relative merits, and the use of the most applicable of these biochemical criteria in the evaluation of nutrition status, have been reported by Du Plessis.[7] Potgieter[8] and Lubbe[9] have described and evaluated the dietary intake methodologies. For the Bantu, Coloured and Indian children, a 24-hour weighing method was used; for the White children, a modification of the Burke dietary history method was employed, which gives an estimation of the habitual food intake at the time of the survey.

TABLE I. AGE AND RACIAL DISTRIBUTION OF CHILDREN INCLUDED IN CORRELATION STUDY

Race:	*White*	*Bantu*	*Coloured*	*Indian*	*White*	*Total number of children*
Survey year:	*1962*	*1963*	*1964*	*1964*	*1965*	*1962–1965*
Age in years:	*7–11*	*7–15*	*7–15*	*7–15*	*12–15*	*7–15*
Total number of children in each racial group	413	549	396	364	241	1,963
Average number of children in each age-group	83	61	44	40	60	—

The dietary data did not include sufficient information for the calculation of individual intakes of saturated and unsaturated fatty acids, and of starch and sugar. A rough estimate has been made of the average intake of starch and sugar of the 7-year-old children. In this study, tryptophan intake has not been taken into account in the evaluation of the nicotinic acid value of the diet. In the analysis of the dietary data, total protein has been divided into protein from animal, plant and mixed animal and vegeable foods respectively. 'Mixed' protein averaged approximately 10% of the total protein intake.

The purpose of the statistical analysis presented in this report was to determine the relationship between the biochemical and the dietary data obtained in the Pretoria surveys. A simple correlation matrix[44] was computed for the dietary and biochemical data. This provides a measure of the linear relationship between any pair of variables. Stepwise regression analyses,[44,45] were carried out to determine the most important dietary influences on selected biochemical parameters. Only the macro-elements and those vitamins which gave the highest simple correlation coefficients were included in the 'stepwise' analyses. Where necessary, partial correlations[44] were also calculated. The statistical analyses were carried out in collaboration with the Statistical Division of the National Research Institute for Mathematical Sciences of the CSIR, using an IBM 360 Model 40 electronic digital computer.

RESULTS AND DISCUSSION

Simple linear correlation coefficients (r) between nutrient intakes and biochemical measurements are given in Table II. It will be noted that the correlation coefficients are all below 0·42.

Possible reasons for these rather low correlations include: (*i*) the problems which are inherent in the collection and interpretation of dietary and biochemical data; and (*ii*) the simple correlation coefficient measures only the strength of the linear relationship between any pair of variables and any non-linear relationship would not be reflected in the correlation coefficient.

Because of the large size of the sample involved (1,963 children) all correlation coefficients greater than 0·08 differ significantly from zero at the 0·1% level, and values greater than 0·04 at the 5% level. Although significant,

TABLE II. SIMPLE CORRELATION COEFFICIENTS BETWEEN DIETARY AND BIOCHEMICAL DATA

Biochemical parameters	*Animal protein*	*Plant protein*	*Mixed protein*	*Calories*	*Total protein*	*Fat*	*Carbohydrate*	*Calcium*	*Phosphorus*	*Iron*	*Vitamin A*	*Thiamine*	*Riboflavin*	*Nicotinic acid*	*Vitamin C*
Serum cholesterol	·24	−·22	·09	·06	·11	·26	−·11	·28	·16	−·10	·22	−·05	·25	·04	·23
Serum phospholipids	·23	−·21	·08	·04	·10	·24	−·11	·28	·15	−·10	·21	−·06	·24	·02	·23
C:P ratio	·11	−·09	·06	·05	·06	·13	−·04	·12	·08	−·06	·12	−·01	·12	·04	·09
Serum amylase	−·22	·15	−·14	−·13	−·14	−·30	·05	−·30	−·20	·08	−·23	−·03	−·25	−·11	−·21
Urinary amylase	−·17	·15	−·18	−·12	−·12	−·30	·06	−·26	−·17	·10	−·20	0	−·23	−·11	−·20
Total serum protein	·01	·05	−·05	·01	·01	−·05	·04	−·04	−·04	·04	−·01	0	−·04	−·01	−·01
Albumin	·26	−·19	·11	·08	·15	·24	−·08	·33	·18	−·05	·24	−·02	·26	·05	·25
Total globulin	−·21	·19	−·13	−·06	−·12	−·24	·09	−·29	−·19	·07	−·20	·01	−·25	−·06	−·22
α-globulin	−·31	·13	−·13	−·19	−·23	−·36	·01	−·39	−·30	·04	−·31	−·09	−·35	−·15	−·29
β-globulin	·17	−·02	·02	·12	·12	·16	·03	·14	·14	0	·14	·06	·16	·14	·13
γ-globulin	−·22	·21	−·12	−·05	−·11	−·23	·10	−·26	−·17	·09	−·19	·03	−·23	−·08	−·21
Albumin as % of total protein	·26	−·22	·15	·08	·15	·28	−·09	·35	·22	−·07	·25	−·01	·29	·06	·27
γ-globulin as % of total protein	−·25	·22	−·13	−·06	−·13	−·25	·10	−·29	−·17	·08	−·21	·03	−·26	−·10	−·24
Urea/creatinine ratio	−·13	−·05	·05	−·12	−·10	−·11	−·09	−·10	−·10	−·04	−·09	−·09	−·13	−·10	−·10
Serum vitamin A	·32	−·08	·08	·18	·25	·27	·04	·33	·28	·01	·24	·11	·31	·13	·25
Serum carotene	·38	−·20	·14	·15	·25	·34	−·05	·41	·30	−·03	·33	·07	·38	·16	·39
Urinary thiamine	−·14	·12	−·14	−·10	−·09	−·23	·03	−·19	−·11	·06	−·14	·02	−·18	−·08	−·17
Urinary riboflavin	·28	−·14	·08	·11	·18	·26	−·04	·37	·26	−·05	·22	·05	·33	·06	·22
Red blood cell riboflavin	·11	−·10	·02	·02	·04	·09	−·05	·12	·08	−·07	·08	−·02	·12	·01	·09
Serum riboflavin	−·10	·11	−·09	−·05	−·05	−·19	·07	−·15	−·08	·08	−·13	·04	−·12	−·05	−·13
Serum FAD	−·03	·07	−·06	−·02	−·01	−·08	·05	−·07	−·03	·06	−·04	·03	−·06	0	−·08
Urinary 2-pyridone	·18	−·14	·10	·03	·11	·17	−·10	·18	·13	−·06	·14	0	·18	·08	·16
Urinary N^1-Me	0	−·15	·12	−·10	−·04	·02	−·17	·05	−·02	−·08	·01	−·10	·01	−·05	·04
2-pyridone: N^1-Me ratio	·22	−·03	·04	·12	·17	·19	·03	·19	·18	−·01	·17	·08	·23	·16	·16
Urinary vitamin C	·02	−·04	0	−·04	−·02	0	−·06	·03	−·01	0	·02	−·03	·01	0	·07
Serum vitamin C	·13	−·03	−·01	·04	·08	·07	0	·12	·08	0	·05	·07	·08	·06	·16
Blood vitamin C	·04	−·06	−·01	−·04	0	0	−·06	·05	0	−·03	0	−·01	·01	−·02	·10

All correlation coefficients greater than 0·08 differ significantly from zero at the 0·1% level.

these values are extremely small. It was therefore decided to interpret the results in terms of the relative magnitude of the correlation coefficients obtained and not in terms of statistical significance.

General Observations

The over-all pattern of correlation coefficients is noteworthy (Table II). When the correlations for individual biochemical measurements with dietary data in general are examined, it is apparent that, for the majority of the dietary variables, positive correlations have been obtained with the following biochemical parameters: serum cholesterol, phospholipids, albumin, albumin as a percentage of total serum proteins, vitamin A, carotene, and urinary riboflavin. Mostly negative correlations have been obtained for dietary data with serum and urinary amylase activity, total serum globulin, α-globulin, γ-globulin, and γ-globulin as a percentage of total serum proteins.

When the correlations for individual nutrients with the biochemical parameters in general are examined, it is apparent that the nutrients that give the highest correlations are animal protein, fat, calcium, vitamin A, riboflavin and vitamin C.

Very low correlation coefficients ($r < 0{\cdot}10$) of individual biochemical parameters (e.g. total serum protein, serum FAD and urinary vitamin C) with dietary parameters partly reflect the unsuitability of these biochemical parameters in the evaluation of nutrition status.[7] Low correlations for individual nutrients in the diet with the biochemical parameters concerned, may be the result of a high intake of these nutrients (e.g. iron and thiamine) by many of the children[46] or may indicate the unsuitability of certain dietary parameters used in this evaluation, e.g. total intake of certain of the B-vitamins, especially nicotinic acid, and the division of protein into 3 classes.

Relationships between Dietary Data and Serum Cholesterol, Phospholipids, Amylase and Urinary Amylase Activity

General. Serum cholesterol and phospholipids correlate similarly with dietary data (Table II). Both show a positive correlation with the dietary intake of animal protein, fat, calcium, vitamin A, riboflavin and vitamin C, and a negative correlation with plant protein and carbohydrate. In contrast, serum and urinary amylase activities show negative correlations with animal protein, fat, calcium, vitamin-A, riboflavin and vitamin-C intakes, and a very small positive correlation with carbohydrate intake.

In experiments on rats, a significant linear correlation has been found between serum cholesterol values and varying amounts of sugar and starch in the diet.[47] The larger the proportion of dietary sucrose and the lower the proportion of starch, the higher is the serum cholesterol. Studies on data from many countries have revealed that there is a relationship between the national sugar consumption and the death rate from coronary heart disease,[48,49] and between the intake of saturated fats and mortality due to coronary heart disease.[50] According to McGandy *et al.*,[51,52] most of the evidence today supports the theory that the intake of fats (amount as well as type) is the most important dietary factor affecting serum lipid values. In many population groups there is a correlation between the consumption of fat and sugar.[50,52,53] In investigating data from different countries, McGandy *et al.*[52] found that the correlation between the consumption of sugar and saturated fat ($r = 0{\cdot}92$) was higher than be-

TABLE III. ESTIMATED STARCH, SUGAR, FAT AND PROTEIN CONSUMPTION OF 7-YEAR-OLD CHILDREN IN PRETORIA

	White	*Indian*	*Coloured*	*Bantu*
Intake (per child):				
Calories	2,060	1,390	1,530	1,580
Total carbohydrate (G)	272	203	239	285
Starch (G)	158	152	187	248
Sugar (G)	114	51	52	37
Fat (G)	81	47	41	29
Protein (G)	64	37	46	46
Animal protein (G)	36	9	14	14
Plant protein (G)	23	21	26	30
Mixed protein (G)	5	7	6	2
% of calories from:				
Carbohydrate	52·4	58·8	63·2	71·9
Starch	30·4	44·1	49·5	62·4
Sugar	22·0	14·7	13·7	9·5
Fat	35·3	30·5	24·5	16·6
Protein	12·3	10·7	12·3	11·5
Animal protein	7·0	2·5	3·7	3·6
Plant protein	4·5	5·9	6·9	7·5
Mixed protein	0·9	2·2	1·6	0·4
% of carbohydrate from:				
Starch	58·1	75·1	78·3	87·0
Sugar	41·9	24·9	21·7	13·0
% of protein from:				
Animal protein	56·3	23·9	30·7	32·1
Plant protein	36·3	55·5	55·8	64·2
Mixed protein	7·5	20·5	13·5	3·6

tween heart disease mortality and dietary sugar (r = 0·80) or between heart disease mortality and saturated fat intake (r = 0·82). Table III gives an indication of the differences in starch, sugar, fat and protein consumption of the 7-year-old children in the 4 racial groups in Pretoria.

In contrast with the results of epidemiological studies[48-51] and experimental work,[24,25,47,52] in which changes in serum cholesterol values were brought about by changes in diet, it has proved difficult to establish in dietary surveys any relationship between serum cholesterol values and the dietary intake of calories, fat, protein and carbohydrate in individuals. Although Gillum *et al.*[53] reported a relationship between protein and fat intakes and serum cholesterol values in ageing Californian subjects, most other workers failed to establish any correlation between serum cholesterol values and dietary practices (intake of calories, fat, protein and carbohydrate) in surveys on adults[38-41,54] and on children.[37,41]

Dietary data and serum cholesterol and phospholipids. In contrast with many dietary survey results, our results show a positive correlation between the total fat in the diet and serum cholesterol (0·26) and phospholipids (0·24). Since data for the intake of saturated and unsaturated fat were not available, the influence of these nutrients on serum cholesterol values could not be determined. However, since there is a closer correlation between animal protein intake and serum cholesterol (0·24) than between the total protein intake and serum cholesterol (0·11); and since, in a South African type of diet, which is generally low in fish, animal protein is more closely associated with saturated fat than with the total fat in the diet, this study does provide indirect evidence of the effect of saturated fat on serum cholesterol values.

The negative correlation between the intake of plant protein and serum cholesterol values (−0·22) may be partly attributed to a low total intake of fat and perhaps of saturated fat in particular (see Table III). The very low correlation between the total intake of carbohydrate and serum cholesterol values (−0·11) probably indicates that the total intake of carbohydrate has little influence on serum cholesterol values.

It was found that there were positive correlations between dietary calcium, vitamin A, riboflavin and vitamin C, and serum cholesterol and phospholipids (Table II). These correlations may perhaps be partly attributed to the type of diet consumed by the children in this study. Those children whose intake of fat and animal protein is high are most likely to consume a diet which is relatively high in other nutrients such as calcium, vitamin A, riboflavin and vitamin C. However, Hard and Esselbaugh,[37] who also reported significant correlations between the intake of these vitamins and serum cholesterol values, mentioned the possibility of a metabolic relationship between the intake of certain vitamins (vitamin A, riboflavin and vitamin C) and serum cholesterol.

Various investigations have illustrated the effect of dietary cholesterol on serum cholesterol values.[55-58] The influence of cholesterol intake on serum cholesterol values could not be evaluated in the Pretoria survey because no intake data for cholesterol were available. However, since animal products contain cholesterol and plant foods are practically cholesterol-free,[59] the intake of cholesterol could have influenced the positive correlations found for the dietary intake of animal protein, fat, calcium, riboflavin and vitamin A, and the negative correlation for the intake of plant protein with serum cholesterol values.

In order to investigate the relative effects of fat and carbohydrate in the diet on serum lipids, correlation coefficients between the percentage of calories from fat, carbohydrates and plant protein, and serum cholesterol were calculated. These results, which are given in Table

TABLE IV. CORRELATION COEFFICIENTS BETWEEN DIETARY PARAMETERS (ENERGY SOURCES, THIAMINE, RIBOFLAVIN) AND SPECIFIC BIOCHEMICAL PARAMETERS

Biochemical parameters	*Animal protein as % of total protein*	*Plant protein as % of total protein*	*% of calories from*			*Thiamine*		*Riboflavin*		
			Fat	*Carbo-hydrate*	*Plant protein*	*Per 1,000 calories*	*Per 100 G carbo-hydrate*	*Per 1,000 calories*	*Per 100 G protein*	*Per 100 G fat*
Serum cholesterol	·28	−·33	·36	−·34	−·35	−·18	·01	·28	·26	−·04
Serum phospholipids	·26	−·31	·36	−·33	−·33	−·18	−·01	·27	·26	−·04
Serum amylase	−·20	·28	−·36	·34	·33	·16	−·03	−·23	−·24	·09
Urinary amylase	−·16	·28	−·38	·35	·33	·19	−·03	−·22	−·24	·10
Urinary thiamine	−·13	·22	−·28	·25	·27	·18	−·03	−·16	−·18	·07
Serum albumin	·30	−·36	·33	−·33	−·35	−·16	·03	·30	·26	0
Total serum globulin	−·23	·31	−·34	·33	·33	·13	−·01	−·27	−·25	·02
α-globulin	−·30	·35	−·38	·37	·37	·12	−·06	−·33	−·32	0
β-globulin	·14	−·12	·10	−·12	−·13	−·04	·05	·12	·12	0
γ-globulin	−·24	·32	−·32	·32	·33	·14	−·01	−·25	−·25	·02
Urinary riboflavin	·29	−·31	·31	−·30	−·31	−·10	·01	·34	·31	·05

IV, show positive correlations between serum cholesterol and the percentage of protein from animal sources, and the percentage of calories from fat, and negative correlations between serum cholesterol and the percentage of protein from plant sources, and the percentage of calories from plant protein and carbohydrate respectively. The most likely reason for the negative correlation between serum cholesterol and the percentage of calories derived from carbohydrate, is the inverse relationship in the diet between the percentage of calories from fat and that from carbohydrate.

The *type* of dietary carbohydrate could also have influenced serum cholesterol values. The negative correlation between serum cholesterol and the percentage of calories from carbohydrate and plant protein, respectively, could perhaps partly be attributed to a high intake of starch. In the 7-year-old children it was found that, when the percentage of calories from carbohydrate and plant protein was high, the percentage of carbohydrate from starch was very high (Table III). It has been shown that starch in the diet, and maize in particular, tends to decrease serum cholesterol both in the rat[60] and in man.[61] Maize, in one form or another, is an important food in the diet of the Bantu. In this study the Bantu children showed low serum cholesterol values (95 and 90% of the 7 - 11 and 12 - 15-year-old Bantu children, respectively, had cholesterol levels below 212 mg./100 ml. serum).[7] Because of insufficient dietary data, the relationship between sugar intake and serum cholesterol values could not be assessed.

Dietary data and serum and urinary amylase activities. Amylase activity is influenced by the intake of starch, but not by the intake of sugar.[62] In this study, the children that have relatively high intakes of both fat and sugar have relatively low intakes of starch (Table III). The inverse relationship between dietary starch and fat is probably the reason for the negative correlation between the intake of fat and serum (−0·30) and urinary (−0·30) amylase activities (Table II) as well as that between the percentage of calories from fat and serum amylase (−0·36) and urinary amylase (−0·38) activities (Table IV).

The extremely low correlations between the total carbohydrate intake and serum amylase (0·05) and urinary amylase (0·06) activities probably reflect to a certain extent sugar in the dietary values for carbohydrate (Table II). Since there is a positive relationship between the percentage of calories from carbohydrate and the percentage of carbohydrate from starch (Table III), the positive correlation coefficients between the percentage of calories from carbohydrate and serum (0·34) and urinary (0·35) amylase activities (Table IV) illustrate the influence of dietary starch on amylase values.

The correlations between plant protein intake and serum (0·15) and urinary (0·15) amylase activities (Table II) are lower than expected if plant protein is taken as an indication of starch intake. The most important reason for these low correlations is the effect which age has on (*i*) food intake, which increases with increasing age,[46] and (*ii*) amylase activities, which decrease with increasing age in children.[7] The percentage of calories derived from plant protein which is not influenced by differences in the intake of food due to age, shows a positive correlation with serum (0·33) and urinary (0·33) amylase activities (Table IV), confirming that starch has an influence on amylase activities.

Partial correlations. Partial correlation coefficients between dietary and biochemical data are given in Table V. The results of this analysis reflect the correlation between a biochemical and a specific dietary variable, with the exclusion of the influence of other dietary variables. The best partial correlations were obtained between fat intake and serum cholesterol (positive), and between fat intake and amylase activities (negative), respectively. Lower correlations were obtained between plant protein intake and amylase activities. This indicates that dietary fat has the greatest influence on serum cholesterol levels, while a high intake of starch (associated with low intakes of fat and high intakes of plant protein) has the greatest influence on amylase activities. Furthermore, the results given in Table VI show that, if the influence of fat intake

TABLE V. PARTIAL CORRELATION COEFFICIENTS BETWEEN DIETARY AND BIOCHEMICAL PARAMETERS

Substance	*Calories*	*Animal protein*	*Plant protein*	*Total protein*	*Fat*	*Carbohydrate*
Serum cholesterol	–0·078	0·060	–0·097	0·007	0·158	0·059
Serum amylase	0·015	–0·014	0·109	0·001	–0·128	–0·018
Urinary amylase	0·033	0·035	0·110	–0·022	–0·156	–0·023

TABLE VI. INFLUENCE OF FAT ON CORRELATION COEFFICIENTS

Substance	*Animal protein*	*Plant protein*	*Total protein*	*Fat*	*Carbohydrate*	*Calcium*	*Vitamin A*	*Riboflavin*	*Vitamin C*
Serum cholesterol	0·24	–0·22	0·11	0·26	–0·11	0·28	0·22	0·25	0·23
Serum amylase	–0·22	0·15	–0·14	–0·30	0·05	–0·30	–0·23	–0·25	–0·21
X serum cholesterol	0·11	–0·28	–0·10	X	–0·21	0·15	0·13	0·12	0·14
X serum amylase	–0·04	0·23	0·11	X	0·16	–0·13	–0·12	–0·08	–0·10

X = influence of fat excluded.

is eliminated, the correlations of the dietary plant protein and carbohydrate with serum cholesterol and serum amylase respectively improve, while correlations between animal protein, calcium, vitamin A, riboflavin and vitamin C in the diet and serum cholesterol or amylase decrease.

'Stepwise' regression analysis. This analysis is a 'stepwise' procedure for calculating a multiple regression relationship between a dependent variable and other specified variables. At each step, the variable that effects the greatest improvement in the correlation coefficient is brought into the calculation. The order of the variables entered gives an indication of their relative importance in relation to the dependent variable.

The results of this analysis in the cases of serum cholesterol and amylase activity are given in Table VII. For serum cholesterol, the most important dietary variables were fat, plant protein and riboflavin, while the intakes of fat and plant protein were the most important in relation to amylase activity.

The similarity of the results for serum cholesterol and serum amylase activity cannot be explained by the existence of a close relationship between these parameters in our data ($r = 0{\cdot}21$), though both are influenced by diet. The intake of fat correlated most closely with both biochemical parameters, followed by that of plant protein. The intake of riboflavin correlated more closely with serum cholesterol than with serum amylase (riboflavin is found in foods relatively high in protein and fat, which may have influenced cholesterol values). Because of the fact that if two parameters correlate very closely, only one of them gives rise to a marked improvement in the multiple correlation coefficient, while the other appears to have much less influence, and because plant protein and carbohydrate intakes are related ($r = 0{\cdot}75$), carbohydrate appears to have the least influence—if, in fact, any at all—on these two biochemical parameters.

This study shows that a high fat intake and, to a greater extent, a high percentage of fat calories are associated with high serum cholesterol levels and with low serum and urinary amylase activities, while a high percentage of calories derived from carbohydrate and from plant protein is associated with low serum cholesterol levels and high amylase activities. It seems, therefore, as if a high serum cholesterol level indicates a habitually high intake of fat, while high amylase activities indicate a high intake of starch. These findings confirm the conclusions reached by Du Plessis,[1] which were based on group mean values, namely that serum cholesterol concentrations and amylase activities may indicate the habitual consumption of fat and carbohydrate.

Protein

Simple correlation coefficients calculated for dietary intake and serum protein fractions, are given in Tables II and IV. The concentration of total serum protein shows only very small correlations with dietary factors. Both serum albumin, and albumin as percentage of total serum proteins, correlate positively with the intakes of animal protein, fat, calcium, vitamin A, riboflavin and vitamin C, and negatively with the intake of plant protein. Many of these correlations are probably influenced by the type of diet habitually consumed by the population groups in this study. Children (Whites) who have a high intake of animal protein are also likely to have a well-balanced diet and a high intake of fat, calcium, vitamin A, riboflavin and possibly also of vitamin C. The total serum globulin, α-globulin, γ-globulin, and γ-globulin as a percentage of the total serum proteins, on the other hand, show negative correlations with the intakes of animal protein, fat, calcium, vitamin A, riboflavin and vitamin C. Serum β-globulin shows small positive correlations and urinary urea/creatinine ratios show small negative correlations with the dietary intake of most nutrients.

Values for the total serum protein and/or albumin are commonly used as criteria of nutrition status. Little is known about the relationships of serum globulins to nutrition status.

Fry and Fox[63] studied the influence of diet on serum protein fractions in 288 Chinese children from Hong Kong aged from 8 to 17 years, by substituting wheat for half the rice in the diets of 141 children. The wheat-rice diet provided larger amounts of all the essential amino acids as well as a slightly higher protein intake (62 G) than the rice diet (56 G). Serum albumin values were higher, while serum globulin values were lower for the children on the wheat-rice diet than for the children on the rice diet. There was a positive relationship between serum albumin values and the quantity as well as the quality of protein in the diet. In a study on orphanage children in the USA, Mack[64] found that serum albumin values increased when meat in the diet was increased, while globulin values increased where diets rich in plant protein were given. Relatively high γ-globulin values have been reported for Indian vegetarians compared with non-vegetarians.[65] Arroyave *et al.*[66] reported a decrease in γ-globulin values when the intake of protein—and especially that of animal protein—increased in the diets of Guatemala orphans. Scrimshaw *et al.*[67] found low serum albumin levels, high levels of α- and γ-globulins and normal β-globulin values in kwashiorkor patients.

TABLE VII. RESULTS OF 'STEPWISE' REGRESSION ANALYSIS FOR SERUM CHOLESTEROL AND AMYLASE

Dependent variable:	*Serum cholesterol*	*Serum amylase*
Dietary variable entered:	1 (+)* Fat	(—) Fat
	2 (—) Plant protein	(+) Plant protein
	3 (+) Riboflavin	(—) Vitamin A
	4 (+) Vitamin C	(—) Vitamin C
	5 (+) Vitamin A	(—) Riboflavin
	6 (+) Animal protein	(—) Total protein
	7 (+) Total protein	(—) Animal protein
	8 (—) Carbohydrate	—

* The signs in brackets are those of the simple correlation coefficients (Table II).

For serum albumin our results (Tables II and IV) show positive correlations with the intake of total protein (0·15), animal protein (0·26) and fat (0·24), animal protein as a percentage of the total protein (0 30), and the percentage of calories from fat (0·33). Negative correlations for serum albumin were obtained with plant protein as a percentage of the total protein (−0 36) and the percentage of calories from carbohydrate (−0 33) and plant protein (−0·35), respectively. There are good correlations between dietary fat and animal protein (r = 0 62), and between dietary carbohydrate and plant protein (r = 0·75). A high intake of animal protein is associated with high serum albumin values while a high intake of plant proteins is associated with low albumin levels. Our results show, therefore, that serum albumin levels give an indication not only of the quantity, but also of the quality of protein in the diets of children.

Our results also indicate that there is an inverse relationship between the quality of protein in the diet and serum globulin values (total, α and γ). A high intake of plant proteins is associated with high globulin values, while a high intake of animal proteins is associated with low globulin values. The influence of dietary protein on serum globulin values is most marked for α-globulin. Beta-globulin values show small correlations with most nutrient intakes and do not appear to be influenced to any great extent by diet.

Some workers[68-70] regard the urinary urea/creatinine ratio as a good criterion of protein nutrition status, a low ratio reflecting sub-optimal protein intake. Our results for urinary urea/creatinine ratios, on the other hand, show small negative correlations with nutrient intake and substantiate the view of Du Plessis[7] that urea excretion is of little value in the evaluation of protein nutrition status.

The lack of correlation between dietary intake and total serum protein values confirms the findings of various workers,[7,68,71-75] that total serum protein in itself is of little value in the assessment of nutrition status.

'Stepwise' regression analysis. The results of this analysis regarding the serum protein fractions, presented in Table VIII, will help to clarify the influence of dietary factors on these biochemical measurements.

The influence of protein quality on serum albumin values is illustrated by the results of the 'stepwise' regression analysis. The first, second and third variables entered can all be related to protein quality. (The intake of animal protein, a good dietary indication of protein quality, correlates best with serum albumin values; a high intake of fat is associated with a high intake of protein (r = 0·71).) Therefore it appears that the use of serum albumin values as a criterion for the assessment of protein nutrition status is justifiable.

The results for total serum globulin and γ-globulin are very similar. An inverse relationship exists between the intake of riboflavin and serum globulin values. The intake of riboflavin is associated with the intake of protein (total and animal), of fat and of calcium. In this survey, those children (Bantu) who had a low intake of these nutrients were also those likely to be more exposed to infections and parasitic infestations such as bilharzia. High total serum globulin and γ-globulin values may therefore reflect a low dietary intake, or exposure to infectious diseases, or both.

The relationship between α-globulin and fat intake is difficult to explain. There is a good correlation between fat and protein intake (r = 0·71), but this fact does not explain why fat intake correlates better with α-globulin than protein intake. The difference in the results for α- and γ-globulin could in part be ascribed to the influence of antibody formation resulting from infection, on γ-globulin values. It is also possible that α-globulin values may reflect the relative amounts of fat and carbohydrate (or animal and plant protein) in the diet, since high α-globulin values are associated with high intakes of carbohydrate and plant protein, while low α-globulin values are associated with high intakes of fat.

The dietary factor which correlates best with β-globulin is animal protein; the correlation coefficient between these two parameters, however, is relatively small (0·17) indicating that dietary protein has a very limited influence, if any, on β-globulin values.

Vitamin A

Simple correlation coefficients between dietary data and serum vitamin A and carotene are given in Table II. The correlation between dietary vitamin-A values and serum carotene (0·33) is higher than that between vitamin-A intake and serum vitamin A (0·24). This can probably be

TABLE VIII. RESULTS OF 'STEPWISE' REGRESSION ANALYSIS FOR SERUM PROTEINS

Dependent variable	*Serum albumin*	*Total serum globulin*	*α-globulin*	*β-globulin*	*γ-globulin*
Dietary variable entered:	1*(+) Animal protein	(—) Riboflavin	(—) Fat	(+) Animal protein	(—) Riboflavin
	2 (—) Plant protein	(+) Plant protein	(+) Plant protein	(+) Vitamin A	(+) Plant protein
	3 (+) Fat	(—) Fat	(—) Vitamin A	(+) Vitamin C	(—) Fat
	4 (+) Vitamin C	(—) Vitamin C	(—) Vitamin C	(+) Fat	(—) Vitamin C
	5 (+) Vitamin A	(—) Vitamin A	(—) Riboflavin	(+) Total protein	(—) Animal protein
	6 (+) Total protein	(+) Carbohydrate	(—) Animal protein	(+) Carbohydrate	(—) Vitamin A
	7 (—) Carbohydrate	(—) Total protein	(—) Total protein	(+) Riboflavin	(+) Carbohydrate
	8 (+) Riboflavin	(—) Animal protein	(+) Carbohydrate	(—) Plant protein	(—) Total protein

* Signs in brackets are those of the simple correlation coefficients.

ascribed to the fact that serum vitamin-A values are influenced by stores in the liver as well as by dietary intake, while values for serum carotene reflect recent dietary intake. In a study of Guatemala orphans, Arroyave *et al.*[47] found that diet had a much greater influence on serum carotene than it had on serum vitamin A. A lack of correlation between recent dietary intakes and serum vitamin-A levels in children has been reported by Donald *et al.*,[33] Warnick *et al.*,[76] and Babcock *et al.*[77] Odland and Ostle,[78] on the other hand, reported a positive though small relationship between recent dietary intakes and serum vitamin-A levels in children. Significant positive correlations between vitamin-A intake and serum carotene values were found by Donald *et al.*,[33] Warnick *et al.*,[76] and Babcock *et al.*,[77] but not by Tucker *et al.*[79] Donald *et al.*[33] also reported highly significant correlations between carotene intake and serum carotene values. Since, in our study, dietary carotene and vitamin A were not assessed separately, the influence of carotene intake on serum values could not be determined.

'Stepwise' regression analysis. The results of this analysis for serum vitamin A and carotene, given in Table IX, show that levels of serum vitamin A correlate best with the intake of animal protein. This probably reflects the influence of preformed dietary vitamin A, which is found only in animal products.

TABLE IX. RESULTS OF 'STEPWISE' REGRESSION ANALYSIS FOR VITAMIN A

Dependent variable:	*Serum vitamin A*	*Serum carotene*
Dietary variable entered:	1 (+)* Animal protein	(+) Vitamin C
	2 (+) Vitamin C	(+) Animal protein
	3 (+) Vitamin A	(—) Plant protein
	4 (—) Plant protein	(+) Vitamin A
	5 (+) Total protein	(+) Fat
	6 (+) Fat	(+) Riboflavin
	7 (+) Riboflavin	(+) Total protein
	8 (+) Carbohydrate	(—) Carbohydrate

* The signs in brackets are those of the simple correlation coefficients (Table II).

Values for serum carotene correlate best with the intake of vitamin C. The possibility of there being a metabolic relationship between vitamins A and C[80,81] may have influenced the correlation between vitamin-C intake and serum carotene values. It has been demonstrated that vitamin C has a sparing effect on several vitamins, including vitamin A.[82]

Thiamine

Simple correlation coefficients between dietary and biochemical data for thiamine are given in Tables II and IV. There is no correlation between urinary thiamine per gram of creatinine and the total intake of thiamine or thiamine/100 G of carbohydrate, while thiamine/1,000 calories and urinary thiamine show a small positive correlation.

Stearns *et al.*[36] reported relatively little variation in excretions of thiamine in children consuming 0·5 mg. of thiamine or less per day; when dietary intake was higher, urinary excretions varied widely. A relatively high intake of thiamine by the children in our study could be one of the reasons for the limited correlation between dietary intake and urinary excretion of thiamine.

Other possible reasons for the small correlation include the influence of sex[7,83] (boys excrete relatively more thiamine than girls) and age[7,84] (excretions of thiamine per gram of creatinine decrease with increasing age) on the urinary excretion of thiamine and the relationship between the intake of calories and carbohydrate and thiamine requirements. Thiamine requirements are reported to be related to both calories and carbohydrate in the diet, but particularly to the latter.[85] Our results, which confirm the findings of Arroyave *et al.*,[86] indicate that the influence of calorie intake on thiamine requirements is more important than that of carbohydrate intake. (The correlation coefficient for urinary thiamine excretion with thiamine intake/1,000 calories is 0·18, while that with thiamine intake/100 G carbohydrate is −0·03.)

Riboflavin

Biochemical tests for evaluating riboflavin status include the measurement of urinary excretions and the determination of blood concentrations. Correlation coefficients between the intake of riboflavin, and riboflavin in blood and urine, are given in Tables II and IV. Dietary riboflavin correlates better with the urinary excretion of riboflavin per gram creatinine (0·33), than with red cell riboflavin (0·12), total serum riboflavin (−0·12), or serum riboflavin adenine dinucleotide (FAD) (−0·06). These results support the conclusion reached by Du Plessis[7] that the urinary excretion of riboflavin per gram creatinine is the most suitable biochemical criterion of riboflavin nutrition status.

Currently, riboflavin requirements are estimated in terms of the intake of calories[34] or of protein.[86] Horwitt[86] is of the opinion that there is a closer relationship between riboflavin and protein requirements than between riboflavin requirements and the intake of calories, and that allowances of riboflavin should be based on those of protein. According to Arroyave,[87] a high intake of fat may increase riboflavin requirements. In this study, the total intake of riboflavin (0·33), of riboflavin/1,000 calories (0·34) and of riboflavin/100 G protein (0·31) all correlated well with the urinary excretion of riboflavin (Table IV), indicating that both calories and protein could be used as a basis for calculating riboflavin requirements in growing children. Since there is no correlation between the intake of riboflavin/100 G fat and urinary excretions (0·05), our findings do not confirm the views of Arroyave that the intake of fat might influence riboflavin requirements.

Since foods rich in protein and fat are important sources of dietary riboflavin, the positive correlations of dietary calcium, animal protein, fat, and the percentage of calories from fat with urinary riboflavin probably reflect the intake of riboflavin.

'Stepwise' regression analysis. The results of this analysis in the case of riboflavin are given in Table X.

Urinary riboflavin correlates best with dietary riboflavin. The 2nd, 3rd, 4th and 5th variables entered can all be related to the intake of protein. These results support Horwitt's view that the requirement of riboflavin is related to that of protein.

TABLE X. RESULTS OF 'STEPWISE' REGRESSION ANALYSIS FOR RIBOFLAVIN

Dependent variable:		*Urinary riboflavin*
Dietary variable entered:	1	(+)* Riboflavin
	2	(—) Plant protein
	3	(+) Fat
	4	(+) Animal protein
	5	(+) Total protein
	6	(+) Vitamin C
	7	(—) Carbohydrate
	8	(+) Vitamin A

* The signs in brackets are those of the simple correlation coefficients (Table II)

The results for riboflavin therefore indicate that both calories and protein requirements may be used as a basis for calculating riboflavin requirements in children.

Nicotinic Acid

The excretion of N^1-methyl nicotinamide (N^1-Me) has generally been used to determine nicotinic acid nutrition status.[88] The development of suitable methods for determining N^1-methyl-2-pyridone-5-carboxylamide (2-pyridone) has made it possible to use the excretion of both N^1-Me and 2-pyridone to evaluate nicotinic acid status.

Simple correlation coefficients between dietary and biochemical data for nicotinic acid are given in Table II. The dietary data for nicotinic acid show no correlation with urinary N^1-Me (−0·05) and 2-pyridone (0·08) excretions, and a small correlation with the 2-pyridone/N^1-Me ratio (0·16).

The relatively small correlations between the dietary and biochemical data for nicotinic acid can be ascribed to (*i*) the data for the intake of nicotinic acid, which include only preformed nicotinic acid (tryptophan intake was not recorded in these surveys), and (*ii*) the nicotinic acid in maize which is, to a large extent, present in a bound form unavailable to man.[35] It is therefore clear that the dietary data for nicotinic acid can give a misleading indication of nicotinic acid status.

The correlation results for N^1-Me, 2-pyridone, and the 2-pyridone/N^1-Me ratio support the conclusions reached by Du Plessis[7] that the 2-pyridone/N^1-Me ratio is a better criterion of nicotinic acid status than N^1-Me excretion alone.

Vitamin C

Correlation results for vitamin C are given in Table II. Positive correlations between vitamin-C intake and serum levels in children have been reported by Hard *et al.*,[89] Roderuck *et al.*,[90] and Arroyave *et al.*[66] Our results show little correlation between the dietary data and serum and blood vitamin-C values. Possible reasons for these low correlations include:

(*i*) Serum and blood vitamin-C values were available only for the 1964 and 1965 surveys (1,001 children, older White, Coloured and Indian children; see Table I) resulting in a relatively homogeneous group.

(*ii*) Dietary and biochemical data were not always obtained on the same day; the dietary data for the non-White children represent the vitamin-C intake on a specific day and that of the White children the habitual intake, while serum vitamin-C levels reflect recent dietary intake.

Data for urinary excretion of vitamin C were available for all the children, but do not correlate with dietary vitamin C. Results for urinary vitamin C indicate that there is little difference in vitamin-C nutrition status between the 4 racial groups,[7] while dietary data for vitamin C indicate that there are considerable differences.[46] There are two possible explanations for the lack of correlation observed:

(*i*) When intake is high, the amount excreted varies considerably.[91] An intake of vitamin C which is well above the minimal requirements in the case of most children could account for the low correlations obtained.

(*ii*) The possibility of a racial difference in vitamin-C metabolism does exist. No explanation can as yet be given for the finding that Bantu children having a low vitamin-C intake are able to excrete relatively large amounts of vitamin C in their urine.[91-93] Reports indicate that clinical scurvy among Bantu children is rare.[92-94]

On the basis of this study, no definite conclusions regarding the biochemical parameters for vitamin C can be reached, although values for blood and serum vitamin C appear to be more suitable criteria than those for urinary vitamin C in the evaluation of vitamin-C status.

CONCLUSIONS

This study demonstrates the influence of dietary fat, particularly of the percentage of calories from fat on serum cholesterol values, a high intake of fat being associated with high serum cholesterol values. There is also indirect evidence that a high intake of starch (maize) is associated with low cholesterol values. Our results support the hypothesis that dietary factors are at least partly responsible for the differences in serum cholesterol values found between Bantu and White population groups. It is significant that this dietary influence can be demonstrated in children. This study indicates that measures for lowering blood cholesterol levels, in an attempt to lower the incidence of atherosclerosis, should be initiated during childhood.

There is a positive relationship between starch intake and serum and urinary amylase activities. The good positive correlations between serum cholesterol and the percentage of calories from fat, as well as between amylase activities and the percentage of calories from plant protein and carbohydrate, support the hypothesis that these biochemical parameters indicate the habitual intake of fat and starch respectively.

Valuable results regarding the relationship between dietary protein and serum protein fractions have been obtained. Since serum albumin is related to both the quality and the quantity of protein in the diet, the use of serum albumin as a criterion of protein nutrition status appears justifiable. An inverse relationship exists between serum globulin values (total, α and γ) and the dietary intake of animal protein, fat, and the percentage of calories from fat, while a direct relationship exists between serum globulin values (total, α and γ) and the intake of plant protein and the percentage of calories from plant protein and carbohydrate respectively. These correlations are especially noticeable in the case of α-globulin, and seem to indicate that values for serum globulin (total, α and γ) could perhaps be used to evaluate protein nutrition, or to give an indication of the relative proportion of carbohydrate and fat in the diet.

Total serum proteins, serum β-globulin and excretions of urinary urea show little relation to dietary intake, and

are, therefore, not considered as suitable criteria for the evaluation of nutrition status.

The vitamin-A value of the diet correlated more closely with serum carotene than with serum vitamin A. This probably reflects the contribution of dietary carotene towards vitamin-A nutrition. These results support the use of serum vitamin A and carotene as criteria in nutrition surveys.

Of the biochemical parameters used for riboflavin (riboflavin concentrations of serum and red cells, serum FAD and urinary excretion), only urinary riboflavin correlates well with dietary intake, and urinary riboflavin is therefore considered to be the most suitable biochemical criterion for the evaluation of riboflavin nutrition status. Our results also indicate that riboflavin requirements are related to the intake of calories and protein but not to the intake of fat. This study does not resolve the question of whether riboflavin allowances should be calculated in terms of protein or calorie requirements. It appears that both methods are suitable for children.

The 2-pyridone/N^1-Me ratio appears to be more suitable than either 2-pyridone or N^1-Me excretions for the evaluation of nicotinic-acid status. The relatively low correlations between the intake of nicotinic acid and the biochemical parameters for nicotinic acid in this study may be ascribed to the fact that the intake of tryptophan was not recorded, and to the unavailability of most of the nicotinic acid present in maize.

It appears that the dietary intakes of animal protein, calcium and riboflavin constitute the best dietary criteria of the general nutrition status of the Pretoria children. Among the biochemical parameters, serum carotene shows the greatest positive correlations and serum α-globulin the greatest negative correlations with dietary parameters in general.

Recommendations

More studies of this nature should be undertaken on children as well as on adults to confirm the general validity of these deductions in other areas and populations.

It is recommended that, in future surveys, the dietary data should include information on the intake of starch, sugar, saturated and unsaturated fatty acids, cholesterol, tryptophan and carotene, as well as preformed vitamin A, as this information would considerably increase the usefulness of the data.

The determination of serum triglycerides should also be undertaken in future surveys, but phospholipid determinations are felt to be unnecessary as cholesterol and phospholipids gave virtually the same results in this study. The total serum and red blood cell riboflavin, serum FAD, and the excretion of urinary urea proved to be unsuitable criteria for the evaluation of nutrition status, as these parameters showed little relationship to dietary intake; it therefore seems unnecessary to determine them. More studies are needed to determine the suitability of the different biochemical parameters for the assessment of vitamin-C nutrition status.

If attempts are to be made to lower the incidence of atherosclerosis in the Republic, they should be initiated during childhood. Dietary guidance for children should therefore also include information on the dangers of excessive fat and calorie intake. Our aim should be not only to prevent undernutrition, but also to eliminate overnutrition.

SUMMARY

To determine the relationship between dietary and biochemical data and to evaluate the suitability of various parameters as criteria of nutrition status, an intercorrelatory study was carried out on data from a comprehensive nutrition status survey on schoolchildren aged 7 - 15 years from the 4 main racial groups (White, Bantu, Coloured and Indian) in the Pretoria area. Simple correlation coefficients, 'stepwise' regression analyses and partial correlations were calculated.

The results for serum lipids showed that there was a relationship in these children between high fat intakes and high serum cholesterol values. Since the dietary data did not permit the calculation of starch intake in individual children, the intake of plant protein was used to provide an indication of the probable intake of starch. A relationship was found between a high intake of plant protein and low serum cholesterol and high amylase activities. Serum lipid and amylase activity values are possibly indicative of habitual intakes of fat and starch, respectively, and measures for lowering serum cholesterol in an attempt to lower the incidence of atherosclerosis should be initiated during childhood.

The data for protein nutrition showed that, of the criteria generally used to evaluate protein status—i.e. total serum protein, serum albumin, and urinary urea excretion—only serum albumin showed a positive correlation with the dietary intake of protein, particularly that of animal origin. Of the criteria that were used, albumin gives the best indication of protein nutrition status in mixed population groups. The serum globulins (total, α and γ) showed positive correlations with the intake of plant protein and carbohydrate, and negative correlations with the intake of animal protein and of fat. Of these correlations, that for α-globulin was especially noticeable, and they seem in general to indicate that the globulins could possibly be used to evaluate protein nutrition.

The vitamin A value of the diet correlated positively with both serum carotene and serum vitamin A. Of urinary riboflavin excretion, red blood cell and total serum riboflavin and serum FAD, only urinary riboflavin correlated well with dietary intake of riboflavin. Of urinary 2-pyridone, N^1-Me, and the 2-pyridone/N^1-Me ratio, the last-mentioned criterion gave the best correlation with nicotinic acid intake. The results confirm the conclusions of other workers, that, of the various criteria used, urinary riboflavin and the 2-pyridone/N^1-Me ratio give the best indication of riboflavin and nicotinic acid status, respectively. Neither the intake of thiamine nor that of vitamin C correlated well with the respective biochemical parameters for these nutrients, i.e. urinary thiamine and vitamin C, and serum and blood vitamin C.

It is recommended that in future surveys data be collected on the intake of sugar, starch, type of fat and tryptophan, and that serum triglycerides be determined.

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