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Etiological Determinants of Protein Calorie Undernutrition in a Rural Child Community

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Abstract

Two groups of randomly selected underweight and well-nourished preschool children residing in study villages of Punjab, Ludhiana district were examined with respect to their socioeconomic background, birth weights, dietary intakes, quality of received mother care, blood biochemistry, parasite load, psychomotor development and past illness prevalence [1]. It was found that underweight children showed significantly less favourable indices in all of the above categories except stool parasitology suggesting an extremely intricate and complex interaction of a host of ecological variables in the causation of undernutrition. Using the discriminate analysis on readily available social variables, it was found that caste affiliation and, less so parental income were the two most significant variables distinguishing between the two groups. A model for the interaction patterns of ecological variables in their effect of protein calorie malnutrition for the given area is suggested.

I. Introduction

The etiology of protein calorie malnutrition (PCM) in a specific child community is complex and, depending on the local situation, may require examination of a wide spectrum of political, socioeconomic and clinical parameters for its elucidation.

Immediate causes for the individual child, on the other hand, can be more readily identified and are found to be similar if not identical in most parts of the lesser developed world. An examination of these is essentially limited to the identification of reasons for decreased food intake, decreased utilization and/or increased food expenditure as the principal component(s). *Decreased food intake* itself may be caused by a number of underlying conditions such as: 1) lack of food because of poverty or famine; 2) anorexia resulting from an acute or chronic illness; or a condition making food intake painful; 3) frequently maternal ignorance as to proper child feeding almost invariably conditioned by local beliefs and traditions; and 4) child neglect similarly influence both the quality and quantity of the child's diet. *Decreased food utilization* often caused by a host of gastrointestinal conditions may also, at times, be inadvertently induced

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[1] In the selection of the underweight group care was taken not to include children that suffered from intercurrent illness or who were considered undernourished by the village community.

iatrogenically as local treatment for a given childhood ailment. *Increased food expenditure* is usually related to increased physical activity, climatic stress, or increased metabolic rate as in illness, notably fever, injury, or any inflammatory reaction (GANDRA & SCRIMSHAW, 1961; BEISEL, 1966). In each case, if the metabolic requirements are not met, energy deficits are made up through protein catabolism with a resultant deficiency state reflecting the nature of the limiting nutrient or nutrients.

In this survey, an attempt has been made to determine and examine some of the conditions leading to decreased food intake, utilization and increased food expenditure which may be conducive to and/or associated with PCM in the rural Punjabi preschool child and to develop means of identifying children at risk of becoming malnourished.

II. Methodology

For this purpose, a randomly selected group of underweight children was compared to a well-nourished control group matched for age and living in the same ecosystem with respect to climate and village community life. All children resided in villages which at the time of this investigation were part of the Narangwal Nutrition Study, R.H.R.C.[2], in Punjab, North India. None of these children were considered malnourished by the community they resided in and apart from appearing perhaps a bit thinner and paler were part of the normal child population of the village and participated in normal daily activities of a rural Indian child community.

A. Sample Selection

The Narangwal Nutrition Study's main objectives were to determine the effects of differential child care services – nutrition supplementation and infectious disease control singly or in combination – on parameters of child health. For this purpose three groups of villages were provided different service packages with a fourth group, receiving no services other than emergency care, serving as control. For this present investigation, all children in nutrition-supplemented villages of the Nutrition Project between 6 and 36 months of age were divided into two main groups depending on whether their weight for age for the preceding four months was (a) 70% or less of the Harvard Weight for Age Standard (STUART & STEVENSON, 1959), the underweight group, or (b) 80% or more, the well-nourished controls. All those who at the time of selection were not weaned were deleted from both groups because of the difficulty inherent in determining exact dietary intakes in breast-fed infants. Of the remaining children, 25 were then selected from each group through a random sampling process. All children were given a physical examination by a physician with pediatric training. Only those free from any overt illness such as exanthemata, fever, diarrhea, otitis media or other acute or chronic infectious disease, and who appeared normally active were included in the definitive study; defaulters (because of intercurrent illness) were replaced by further random sampling.

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[2] Rural Health Research Centre; a project by the Indian Council of Medical Research and the Department of International Health, The Johns Hopkins University.

B. Parameters of Nutritional Status

1. Anthropometry

All children were weighed to the nearest 50 grams by means of a beam scale calibrated before and after each measurement; height was measured in centimeters to the nearest millimeter with a horizontal infantometer for children below 18 months and in the upright position for all older ones. Head, arm, and chest circumferences were measured with a fiberglass tape to the nearest millimeter according to the guidelines in Jelliffe's monograph on the assessment of the nutritional status of the community (JELLIFFE, 1966).

2. Biochemistry

Blood for haemoglobin, packed cell volume and total serum protein was taken by means of a finger or heelprick. All determinations were done in duplicate. Haemoglobin was measured photometrically by means of a Coleman Junior Photometer and according to the oxyhaemoglobin method (VARLEY, 1967). Packed cell volume and total serum protein were determined by microtechnique using a microhaematocrit reader and refractometer (Goldberg TS meter), respectively. Urinary creatinine excretion was determined on a four-hour morning sample according to the method of FOLIN (1914) and the creatinine-height index calculated according to VITERI and ALVARADO (1970).

C. Measurement of Probable Etiological Factors of Underweight

1. Food Intake

The total daily food intake was determined through a three-day diet observation (weightment method) and the specific nutrient content of the daily diet of each individual child was determined with the help of the ICMR bulletin on «The Nutritive Values of Indian Foods (AYKROD et al., 1966). Preliminary to the study, the composition of the most of the local dishes had been determined for different seasons and socioeconomic groups.

2. Socioeconomic Level

A socioeconomic survey at the time of the dietary investigation provided information on family income, caste, family composition and parental employment status.

3. Level of Mother Care

A comparison between the two groups of children was made by using an observation index based on both subjective and objective criteria (KIELMANN, 1974). The diet investigator who stayed with the family for three days made, in the course of this time and in addition to the diet and socioeconomic surveys, an assessment of the quality of care provided to the child through means of a sequential-observation technique measuring occurrence and frequency of positive or negative "child-family interactions". Each observer was provided with a checklist for observations related to overall care of the child itemized into nutritive, protective, affective and stimulative actions. For each child a total score was thus determined. Children were then assigned to either of two groups, neglected or well-cared for, depending on whether he scored in the 50th or lower or 51st or higher percentile.

4. Morbidity Experience

Since all children included in the study also belonged to the child population of the major investigation on the Interactions of Malnutrition and Infection of the RHRC Nutrition Project, each child's past morbidity experience from its entry into the study cohort, in most cases its birth, to the date this investigation was done, was available and could readily be computed. In the Nutrition Project, past morbidity prevalence was collected routinely by resident auxiliary health workers on every study child once a week through means of a survey based on the mothers' recall for the preceding 6 days, supplemented by physical examination on the day of the visit. Recalled and/or encountered illness was checked off on the morbidity form against a roster of 44 clinical signs, symptoms or symptom groups. Completed forms were sent monthly to the Narangwal central office for data processing.

From this, symptom complexes which seemed to occur most frequently, namely, upper respiratory tract infections (URI), diarrhea, skin and eye infections, and those which may be expected to have a more direct effect on food intake or metabolic need: fever and stomatitis were selected and prevalence rates determined and compared both on a collective and on an individual basis for the two groups.

5. Parasitology

Two samples of morning stool of each child were preserved and stained with the MIF stain and examined microscopically for eggs, larvae and parasites.

6. Knowledge of Child Nutrition

To assess the mothers' knowledge or concept of ideal child feeding, we made use of a survey carried out in the same area on 120 mothers, 60 of them having at least one malnourished child and 60 with one or more well-nourished but no malnourished children[3] in the 6 to 35 month age range. Out of a total of 15 questions in this survey, we considered the following six of particular relevance for inclusion in this study:

a) How soon after birth should the child be put to the breast?
b) Age at which breast feeding should be stopped?
c) Whether breast feeding should be stopped abruptly or gradually?
d) Until what age breast milk alone was sufficient to satisfy the child's nutritional requirements?

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[3] Arbitrarily defined as a child with weight for age at or below 70% of the Harvard median.

e) At what age supplementation should be started?

f) What particular foods should be given and which, if any, should be withheld in a child suffering from any of the three conditions: diarrhea, malnutrition, measles?

7. Birth Weight

For 28 of the children included in the study (15 underweight, 13 well-nourished) birth weight or their weight within the first seven days of life was available.

8. Psychomotor Development

Since we assumed that an active child with normal or advanced psychomotor development may be more able to attract attention and thus be given food and care, or, at a later stage procure food for himself, psychomotor development was assessed in 47 children, 25 well-nourished and 22 underweight. The methodology employed was based on a series of test items derived from the Stanford-Binet, Denver-Colorado and Bailey Standard Tests and modified and adapted for the rural Punjab setting.

D. Analysis

1. Simple Statistical Analysis

Following tabulation of the data according to the two groups and, if found necessary, to subgroups such as age, sex, caste, etc., differences between groups were examined through tests of the null hypothesis using x^2 or student's "t" tests on proportions or sample means respectively. Only Type I errors have been tested for.

2. Discriminant Analysis on Related Variables

The objectives of this analysis were to determine from among all variables examined those that might prove important in the etiology of malnutrition of the selected children, and to determine the power of discrimination of variables readily available through sample surveys or from census records. The particular programme employed was the Stepwise Discriminant Analysis (BMD07M) [4]. In this programme, variables are introduced one at a time in order of their discriminant power. Original variables selected were: Caste, Sex, Age, Birth Order, Parental Income, Father's Occupation, Daily-Protein, Calorie, Vitamin A, Calcium and Iron-Intakes, Percent of Caloric Intake as Protein, individual Morbidity Experience (Fever, Upper Respiratory Infection, Diarrhea, Skin and Eye Infection, Stomatitis), and Level of Mother Care [5]. Set 2 included only social

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[4] University of California: Publications in Automatic Computation, No. 2, BMD, Biomedical Computer Programs, W. J. Dixon, Ed. University of California Press, Berkeley, California 1970.

[5] Birth weight was not included since it was available for only 28 (56%) of the children.

variables that can be made available without in depth survey, namely Caste, Sex, Age, Birth Order, Parental Income and Parental Employment Status.

III. Results

A. Overall Findings

Tables 1 and 2 show the weight, height, head, chest and arm circumferences and their relation to accepted standards. As mentioned previously, children were selected on the basis of their weight. As expected, and for all age groups, height, head, chest and arm circumference when expressed as average percent of the respective standards,

Table 1. Weight and height of study population on day 0 by age groups

AGE GROUP (mos.)	STUDY GROUP	NO	AGE		WEIGHT (Kg)			HEIGHT (cm)		
			X̄	S.D.	X̄	Av.% of St	S.D.	X̄	Av.% of St	S.D.
6 - 15	Malnourished	4	12.5	4.4	6.3	65.0	3.5	66.3	89.5	3.3
	Welln. Controls	2	7.0	1.4	8.0	94.0	2.8	67.0	98.5	2.1
16 - 25	Malnourished	4	22.7	2.6	7.8	64.2	2.3	72.5	85.0	2.2
	Welln. Controls	5	20.0	2.9	10.8	94.6	3.9	83.5	99.6	0.9
26 - 35	Malnourished	16	30.4	2.6	8.8	65.1	4.5	79.1	86.1	3.3
	Welln. Controls	18	30.0	2.9	11.1	85.3	6.7	85.9	94.0	2.8
All Ages	Malnourished	24	-	-	-	65.0	3.9	-	86.0	3.4
	Welln. Controls	25	-	-	-	87.9	7.2	-	95.5	3.4

Significance: t-test: Average weights and heights of the wellnourished when expressed as percent of the Harvard Standard are significantly higher than the malnourished in all age groups.

t for weight (overall) = 13.9; $P < 0.001$.

t for height (overall) = 9.8; $P < 0.001$.

Table 2. Head, chest and arm circumference of study population on day 0 by age group

AGE GROUP	STUDY GROUP	HEAD CIRCUMFERENCE				CHEST CIRCUMFERENCE				ARM CIRCUMFERENCE			
		No	X	Av.% of St	S.D.	No	X	Av.% of St	S.D.	No	X	Av.%of St	S.D.
6 - 15	Malnourished	4	42.2	93.8	1.5	3	41.5	87.0	0.9	3	12.4	79.4	2.2
	Welln. Controls	2	43.8	98.2	0.3	2	43.1	96.9	2.1	1	14.0	90.9	-
16 - 25	Malnourished	4	44.5	93.1	1.9	4	44.3	88.9	4.2	4	12.6	78.9	5.1
	Welln. Controls	5	46.8	97.4	3.1	5	48.0	97.6	5.5	5	15.5	96.2	6.9
26 - 35	Malnourished	16	45.5	92.5	2.2	15	44.8	87.1	1.9	13	13.1	81.4	5.8
	Welln. Controls	17	47.8	96.6	2.1	17	48.3	94.1	2.7	15	14.3	88.3	5.5
All Ages	Malnourished	24	X	92.8	2.0	22	X	87.4	2.4	20	X	80.6	5.2
	Welln. Controls	24	X	96.9	2.2	24	X	94.9	3.3	21	X	90.2	6.7

Significance: t-test: In all age groups as well as in the total group the head, chest and arm circumference when expressed as av. % of respective standard is significantly lower in the malnourished group than in the wellnourished group (P in all cases < 0.05).

Table 3. Selected anthropometric ratios by age and nutritional status

Age Group	Nutritional Group	No.	Anthropometric Ratios											
			Weight/height			Height/head circ.			Height/chest circ.			Height/arm circ.		
			x	s.d.	sig.	x	s.d.	sig.	x	s.d.	sig.	x	s.d.	sig.
6 - 15	Malnourished	4	94.2	8.0	**	1.57	.04		1.63	.04		5.46	0.27	
	Wellnourished	2	119.3	14.8		1.53	.01		1.56	.01		4.82	----	
16 - 25	Malnourished	4	106.9	1.8	***	1.63	.03	***	1.64	.04	*	5.77	0.42	
	Wellnourished	5	131.5	7.2		1.78	.05		1.74	.07		5.40	0.28	
26 - 35	Malnourished	16	111.3	6.4	***	1.74	.07	*	1.77	.10		6.08	0.45	
	Wellnourished	18	129.7	14.0		1.80	.08		1.78	.07		6.03	0.45	
All	Malnourished	24	107.7	8.7	***	1.69	.09	**	1.73	.10		5.92	0.48	
	Wellnourished	25	129.2	13.1		1.78	.10		1.75	.09		5.83	.53	

Statistical significance: * $P < 0.05$; ** $P < 0.005$; *** $P < 0.001$.

Table 4. Selected biochemical and hematologin indices of nutritional status by study group and age

AGE GROUP	STUDY GROUP				BIOCHEMICAL AND HEMATOLOGIN INDICES						
		Haemoglobin			P.C.V.			MCHC*	Total Serum Protein		
		No.	gm%	S.D.	No.	%	S.D.	%	No.	gm%	S.D.
6 - 15	Malnourished	2	8.8	2.47	3	35.6	3.51	24.6	3	7.5	0.47
	Welln. Controls	2	9.1	3.46	2	34.3	6.85	26.4	2	7.5	0.49
16 - 25	Malnourished	4	8.6	1.88	4	34.5	3.10	24.9	4	7.7	0.38
	Welln. Controls	4	7.9	1.93	4	33.8	3.74	23.4	4	7.9	0.56
26 - 35	Malnourished	15	7.7	1.98	15	31.9	5.92	24.1	15	8.1	0.91
	Welln. Controls	16	9.2	1.55	16	35.7	3.11	25.7	16	7.7	0.50
All	Malnourished	21	8.0	1.95	22	32.9	5.29	24.3	22	7.9	0.80
	Welln. Controls	22	8.9	1.75	22	35.2	3.43	25.3	16	7.7	0.49

* Mean corpuscular haemoglobin concentration.

Significance: t-test: 1. The haemoglobin level (gm%) is significantly higher ($P = < 0.05$) in the well-nourished group than the malnourished group as a whole ($P = < 0.05$) in the wellnourished group than the malnourished group as a whole protein as well as PCV between the malnourished and wellnourished groups.

similarly are significantly lower in the underweight [6] than in the well-nourished children.

In Table 3 various anthropometric ratios, weight/height, height/head circumference, height/chest circumference and height/arm circumference have been calculated by age and for the two groups. Weight (gms) per centimeter height is significantly higher among the well-nourished ($P < 0.005$) for all three age groups as well as the group as a whole. The ratio of height over head circumference is significantly lower ($P < 0.05$) among the underweight beyond 15

[6] In all Tables the term "malnourished" has been used instead of underweight.

months of age, as well as the group as a whole and with increasing age tends to increase at a lesser rate among the underweight than among the well-nourished. Height per chest circumference in general does not differ between the two groups except for the 16 to 26 months age group. There was no significant difference between the height over arm circumference ratios between any of the three age groups.

Table 4 shows haemoglobin, haematocrit and total serum protein values. Average Hgb concentrations are significantly higher in the well-nourished than in the underweight groups in total as well as in the 26 to 35 month olds. Differences in Hgb levels between underweight and well-nourished in the 6 to 15 and 16 to 25 months age groups were not found to be statistically significant. Although, both haematocrit and total serum protein values in most age groups were lower in the underweight group, the difference was not found to reach statistical significance.

Table 5 shows the urinary creatinine and the creatinine height index, estimated on a 4 hours' morning specimen. Urinary creatinine excretion and the creatinine height indices (as indicators of muscle mass) were significantly lower in the underweight.

Tables 6 and 7 summarize the diet information. The survey was done during the winter months, when there is a greater availability of green, leafy vegetables, carrots, tomatoes, raw (brown) sugar, and food in general. Daily average protein, calorie, iron, calcium and vitamin A intakes were significantly lower in the underweight than in the well-nourished, as a whole as well as in different age groups. Nutrient intakes in children of the same nutritional status but different caste showed no significant difference. Calorie and protein intakes per centimeter height were significantly lower in underweight children. When nutrient intakes were expressed as fraction of body weight, observed differences did not reach statistical significance. There was no marked difference in percent of calories derived from protein between the two groups: 10.4 and 10.1 for the well-nourished and underweight respectively.

Table 8 provides a breakdown of the study population by caste and sex. Most underweight children (58%) are low caste and female. Overall, both low caste and female sex were found to be significantly more frequent among the underweight group.

Table 9 shows the employment and economic status of the parents of the study population. Parents of well-nourished children are most often land-holding farmers. This is probably a reflection of their caste, as most land owning farmers in rural Punjab are of high caste. Within the high caste, land owning farmers still had the least number of underweight children; however, the difference was not statistically significant. Occupational backgrounds of the high caste fathers other than

Table 5. Urinary creatinine and creatinine height index of malnourished and wellnourished children by age group

AGE GROUP	STUDY GROUP	NUMBER OF CHILDREN	URIN. CREATININE		CREATININE HEIGHT INDEX	
			mg/day	S.D.	Index	S.D.
6 - 15	Malnourished	4	71	55.3	0.81	0.56
	Welln. Controls	2	53	53.7	0.59	0.60
16 - 25	Malnourished	4	27	8.9	0.25	0.06
	Welln. Controls	5	197	78.8	1.18	0.55
26 - 35	Malnourished	16	176	119.5	1.26	0.77
	Welln. Controls	18	288	149.3	1.74	0.86
All	Malnourished	24	134	116.8	1.01	0.76
	Welln. Controls	25	251	147.9	1.49	0.83

Significance: t-test for urinary creatinine excretion between: a) malnourished and wellnourished children = 2.87, $P < 0.01$; b) malnourished and wellnourished in the 16–25 months age range = 4.79, $P < 0.01$.

t-test for creatinine height index between: a) malnourished vs. wellnourished children = 2.11, $P < 0.05$; b) malnourished and wellnourished children in the 16–25 months age group = 3.75, $P < 0.01$.

Table 6. Average daily food intake by nutritional status

Nutrients	Nutritional Status						Statistical Significance
	Wellnourished			Malnourished			
	No.	Average Intake	S.D.	No.	Average Intake	S.D.	
Gm Protein / day	25	32.9	3.5	24	20.8	5.7	***
Gm Protein / Kg. Body wt.		3.1	1.35		2.5	0.98	N.S.
Gm Protein / Cm Height		0.39	0.16		0.27	.08	**
Calories / day	25	1254	437	24	878	259	***
Calories / Kg. Body wt.		117.7	45.1		107.0	36.6	N.S.
Calories / Cm Height		15.0	5.34		11.5	3.38	*
% Calorie present as Protein	25	10.4	2.00	24	10.1	4.08	N.S.
Mg. Iron / day	25	16.2	14.9	24	5.6	3.6	**
Mg. Iron / Kg. Body wt.		14.9	13.3		6.6	3.9	**
Mg. Calcium / day	25	1156	647	24	522	561	***
Mg. Calcium / Kg Body wt.		110.0	67.1		71.6	47.8	*
Vitamin A (I.U.) / day	25	1995	1275	24	611	391	***

* $P \leq 0.01$ N.S = not significant.
*** $P \leq 0.001$ ** $P \leq 0.005$

land owning farmers differ little between the underweight and the well-nourished groups and were: farm laborer, weaver, carpenter, driver; and tailor, driver, shopkeeper and soldier respectively. Their average monthly incomes differed considerably with a mean of 250 Rs. (range 100–400) for the underweight and 390 Rs. (range 200–550) for the well-nourished groups. Overall, the average monthly family income of the underweight child was significantly lower than that of

Table 7. Daily food intake by age and nutritional status

Age Group	N.S.	No.	Average Age in Mo.	Daily Food Intake: Protein gm	Protein S.D.	Calories Cal.	Calories S.D.	Calcium mg	Calcium S.D.	Iron Mg	Iron S.d.	Vitamin A Iu	Vitamin A S.D.
6 - 15 mo.	M.N.	4	12.5	20.5	10.0	862	327	736	482	3.3	2.9	428	290
	W.N.	2	7.0	26.3	14.7	932	434	1076	646	4.9	0.9	1528	1267
16 - 25 mo.	M.N.	4	22.7	18.0	5.3	811	247	392	924	7.5	2.4	617	325
	W.N.	5	20.0	40.1	15.8	1372	446	1328	369	14.0	9.2	2423	1586
26 - 35 mo.	M.N.	16	30.4	21.4	4.6	899	260	555	217	5.7	3.9	637	486
	W.N.	18	30.0	31.6	12.8	1257	492	1117	724	18.1	16.5	1963	1222
ALL	M.N.	24	26.7	20.8**	5.7	878**	259	522**	207	5.6*	3.6	597**	391
	W.N.	25	26.1	32.9**	13.5	1254**	437	1156**	647	16.2*	14.9	2016**	1264
Recommended Daily Dietary Allowance			<1 year	* 14 gms		820		500 - 600		5 - 10		1000	
				**2.2xkg BW.		110xkg BW.		360 - 540		10 - 15		1400 - 2000	
			1-3 years	* 16 gms		1360		400 - 500		5 - 10		830	
				** 23		1300		800		15		2000	

* WHO, Geneva, 1974.

** Recommended Dietary Allowance, 8th Edition, National Academy of Sciences Washington, D.C. Food and Nutrition Board, NRC, 1974.

Table 8. Study population by caste and sex

Study Group	Low Caste: Male No.	%	Female No.	%	M + F No.	%	High Caste: Male No.	%	Female No.	%	M + F No.	%	Both Castes: Male No.	%	Female No.	%	M + F No.	%
Malnourished (< 70% H.St.*)	3	12.5	14	58.3	17	70.8	2	8.3	5	26.8	7	29.2	5	20.8	19	79.2	24	100
Wellnourished Controls (≥ 80% H.St.*)	2	8.4	4	16.0	6	24.0	12	48.0	7	28.8	19	76.0	14	56.8	11	44.0	25	100
Both Groups	5	10.2	18	36.7	23	46.9	14	28.6	12	24.5	26	53.1	19	38.8	30	61.2	49	100

* Harvard Weight Standard.

Significance: χ^2 for number of malnourished children among: a) high caste vs. low caste = 10.6, $P < 0.01$; b) female vs. male = 6.4, $P < 0.02$.

the well-nourished counterpart. It was also significantly lower in the well-nourished of low caste than in those of high caste. Among the underweight the difference in incomes between the high and low castes was not found to be statistically significant.

Tables 10 and 11 show birth order, birth weight, and number of live siblings by nutritional status and caste. Whereas birth order seemed not to have had an effect on the nutritional status of the study children, underweight children tended to have more siblings than well-nourished controls. The observed difference did not reach statistical significance. Birth weight on the other hand, was significantly ($P < 0.005$) lower in underweight children, their mean being around 2500 grams as compared to 3300 grams for controls. The difference became even more pronounced when birth weights of only those who were 24 months or older at the time of this survey, were compared (Table 11).

Table 9. Study population by caste, parental income and employment status

Study Group	Caste	Employment Status: Landowning Farmers No.	%	Others: Agric. Labour No.	%	Other No.	%	All No.	%	Average Monthly Income: Rupies	S.D.
Malnourished (<70% H.St.)	H.C.*	3	13	1	4	3	13	7	29	364	197
	L.C.	1	4	7	29	9	38	17	71	203	79
	BOTH	4	17	8	33	12	50	24	100	260	146
Wellnourished Controls (≥80% H.St.)	H.C.	15	60	0	0	4	16	19	76	679	385
	L.C.	0	0	2	8	4	16	6	24	380	248
	BOTH	15	60	2	8	8	32	25	100	611	376
All Children	H.C.	18	37	1	2	7	14	26	53	587	367
	L.C.	1	2	9	18	13	27	23	47	247	154
	BOTH	19	39	10	20	20	49	49	100	433	334

* H.C. = High Caste; L.C. = Low Caste.

Significance: χ^2 for number of malnourished children among: a) landowning farmers vs. others = 9, $P < 0.01$; b) high caste landowning farmers vs. other high caste occupational groups = 3.14, P = N.S.

t-Test for monthly incomes among: a) all malnourished vs. all wellnourished = 4.34, $P < 0.001$; b) high caste wellnourished vs. low caste wellnourished = 2.23, $P < 0.05$; c) all high caste vs. all low caste = 4.31, $P < 0.001$; d) high caste malnourished vs. low caste malnourished = 2.09, $P < 0.05$.

Table 10. Study population by birth order, caste and number of siblings

STUDY GROUP	CASTE	BIRTH ORDER 1 No	%	2-3 No	%	4-5 No	%	6+ No	%	NUMBER OF ALIVE SIBLINGS 0 No	%	1 No	%	2 No	%	3 No	%	4 No	%	5+ No	%	All No	%
Malnourished (≤ 70% H.St.)	H.C.	4	57	1	14	1	14	1	14	4	57	0	0	1	14	0	0	1	14	1	14	7	100
	L.C.	9	53	3	18	4	24	1	6	5	29	8	47	0	0	2	12	1	6	1	6	17	100
	BOTH	13	54	4	17	5	21	2	8	9	38	8	33	1	4	2	8	2	8	1	8	24	100
Wellnourished Controls (≥ 80% H.St.)	H.C.	9	47	5	26	4	21	1	5	6	32	4	21	4	21	4	21	1	5	0	0	19	100
	L.C.	3	50	20	33	1	17	0	0	3	50	0	0	1	17	2	33	0	0	0	0	6	100
	BOTH	12	48	7	28	5	20	1	4	9	36	4	16	5	20	6	24	1	4	0	0	25	100
All Children	H.C.	13	50	6	23	5	19	2	8	10	38	4	15	3	12	2	8	6	23	1	4	26	100
	L.C.	12	52	5	22	5	22	1	4	8	32	2	8	0	0	5	20	2	8	0	0	23	100
	BOTH	25	51	11	22	10	20	3	6	18	37	6	12	3	6	7	14	8	16	1	2	49	100

Significance: No statistically significant differences between groups.

In Tables 12 and 13 the results on the evaluation of the quality of mother-care are given. The differences in scores between the two groups is significant ($P < 0.01$). This is attributable mainly to the difference in scores among the well-nourished and underweight of high caste. There was no significant difference in the scores of well-nourished and underweight children of the low caste groups.

Tables 14 and 15 present an overview of the prevalence of selected illness symptoms or symptom complexes. Since study children resided both in villages with or without provision of infectious disease control

Table 11. Birth weight of underweight children and wellnourished controls by age

NUTRITIONAL STATUS	AGE GROUP (mos)	#	MEAN BIRTH WEIGHT Kilogms	S.D.
Underweight	<24	4	2.68	0.86
	≥24	11	2.41*	0.49
	All	15	2.48*	0.59
Wellnourished	<24	5	3.26	0.89
	≥24	8	3.41*	0.56
	All	13	3.35*	0.67
All	All	28	2.89	0.76

Significance between two ↑ ↑ values.

* $P < 0.005$.

Table 12. Quality of mother care by study group and caste

Study Groups	Caste	No.	Well Cared For No.	Well Cared For %	Neglected No.	Neglected %
Malnourished	H.C.	7	2	29	5	71
	L.C.	17	8	47	9	53
	Both	24	10	42	14	58
Wellnourished	H.C.	19	19	100	0	0
	L.C.	6	3	50	3	50
	Both	25	22	88	3	12
Both Groups	H.C.	26	21	81	5	12
	L.C.	23	11	48	12	52
	Both	49	32	65	17	35

Significance: χ^2 for number of well cared for and neglected among: a) malnourished and wellnourished = 11.6, $P < 0.01$; b) low caste vs. high caste = 5.84, $P < 0.02$; c) high caste malnourished vs. high caste wellnourished = 17.5, $P < 0.01$; d) low caste malnourished vs. low caste wellnourished = n.s.

services, groups were subdivided accordingly to eliminate a potential source of bias that might be introduced because of possible differential treatment effects and/or illness reporting between the two groups prior to comparison and analysis.

In Table 14 prevalence rates for fever, skin and eye infection, diarrheal disease, upper respiratory tract infection and stomatitis have been determined for each of the two groups of children collectively.

Table 13. Quality of mother care by study group and sex

Study Groups	Sex	No.	Well Cared For		Neglected	
			No.	%	No.	%
Malnourished	Female	19	8	42	11	58
	Male	5	2	40	3	60
	Both	24	10	42	14	58
Wellnourished	Female	11	9	82	2	18
	Male	14	13	93	1	7
	Both	25	22	88	3	12
Both Groups	Female	30	17	57	13	43
	Male	19	15	79	4	21
	Both	49	32	65	17	35

Significance: χ^2 for number of well cared for and neglected among: a) male and female children –2.56, P = n.s.; b) malnourished female vs. wellnourished female children = 4.7, $P < 0.05$; c) malnourished male vs. wellnourished male children = 5.7, $P < 0.02$; d) malnourished and wellnourished = 11.6, $P < 0.01$.

For this the cumulative totals of both duration of symptom or symptom complex and length of observation of all children within each group were used. Groups of underweight children generally had very significantly higher overall illness prevalences than groups of well-nourished children. One group of four underweight children who resided in villages without medical care facilities had a lower prevalence rate of stomatitis and eye infection than the corresponding well-nourished group.

In Table 15 the averages of individual prevalence rates with respect to selected symptoms or symptom complexes are compared among corresponding groups. Eight times in twelve the underweight group had a higher disease prevalence than the corresponding well-nourished group. For diarrheal disease, stomatitis, and eye infection underweight children from villages without medical care facilities and for skin infection underweight children with medical care facilities had, on the average, a lower prevalence rate than their well-nourished counterparts. Except with eye infection prevalence none of these differences reached statistical significance.

Both Tables 14 and 15 further show that the reported and observed illness prevalence may be somewhat influenced by the medical facility available in the village. Thus, prevalence rates are more often higher in villages with medical care facilities than in those without.

Table 14. Collective prevalence of selected symptoms and symptom complexes in groups of malnourished and wellnourished children by availability of medical care facilities

STUDY GROUP	MEDICAL CARE FACILITY IN VILLAGE	Children Observed		Total duration and prevalence of symptom and symptom complexes											
				Fever		Skin Inf.		Diarrheal Dis.		U.R.T.I.		Stomatitis		Eye Infection	
		No.	Total Days of Obs.	Total no. of Days	Prev. %	Total no. of Days	Prev. %	Total no. of Days	Prev. %	Total No. of Days	Prev. %	Total no. of Days	Prev. %	Total no. of days	Prev. %
Malnourished	Absent	4	1920	82	4.3	157	8.2	223	11.6**	233	12.1	10	0.5	47	2.4
	Present	20	13680	521	3.8*	812	5.9	1563	11.4**	2660	19.4	561	4.1	1204	8.8**
	Both	24	15600	603	3.9	969	6.2	1786	11.4	2893	18.5	571	3.7	1251	8.0*
Wellnourished	Absent	13	8400	190	2.3	508	6.0	584	7.0	989	11.8	128	1.5	507	6.0
	Present	11	8640	283	3.3*	439	5.1	736	8.5	1498	17.3	195	2.3	732	8.5**
	Both	24	17040	473	2.8	947	5.6	1320	7.7	2487	14.6	323	1.9	1239	7.3*
All	Absent	17	10320	272	2.6	665	6.4	707	7.9	1222	11.8	138	1.3	554	5.4
	Present	31	22320	804	3.6	1251	5.6	2299	10.3	4158	18.6	756	3.4	1936	8.7
	Both	48	32640	1076	3.3	1916	5.9	3006	9.2	5380	16.5	894	2.7	2490	7.6

Probabilities that the observed differences are by chance (using the χ^2 test).
* P = $<$ 0.05, ** P = n.s.
P = $<$ 0.01 for all remaining inter and intra group comparisons.

Table 15. Average prevalence of selected symptoms or symptom complexes in malnourished and wellnourished children by availability of medical care facilities

STUDY GROUP	MEDICAL CARE FACILITY IN VILLAGE	Children Observed		Average Prevalence of Symptoms or Symptom Complexes											
				Fever		Skin Inf.		Diarreal Dis.		U.R.T.I.		Stomatitis		Eye Infection	
		No.	Av.Duration of Obs.Days	Av.Prev. %	S.D.	Av.Prev. %	S.D.	Av.Prev. %	S.D.	Av.Prev. %	S.D.	Av.Prev. %	S.D.	Av.Prev. %	S.D.
Malnourished	Absent	4	480	4.5	3.4	6.2	6.6	7.9	5.4	14.4	8.0	0.3	0.6	2.1**	1.7
	Present	20	684	3.7	2.1	5.4	5.6	12.3*	8.3	19.9	17.0	3.7	6.2	10.6	7.2
	Both	24	650	3.8*	2.3	6.5	7.3	11.5	7.9	19.0	15.8	3.1	5.8	8.8	7.3
Wellnourished Control	Absent	13	646	2.4	2.5	5.9	5.5	8.3	7.8	13.4	14.6	2.2	3.2	6.1**	4.7
	Present	11	785	3.0	1.9	6.7	9.1	7.8*	6.1	19.1	10.9	2.0	3.7	8.2	6.3
	Both	24	709	2.6*	2.2	6.3	7.2	8.1	6.9	16.0	13.1	2.2	3.4	7.1	5.5
All	Absent	17	607	2.9	2.7	5.9	5.6	8.2	7.1	13.6	13.1	1.7	2.9	5.0	4.4
	Present	31	720	3.4	2.1	5.9	6.9	10.7	7.8	19.6	14.9	3.1	5.4	9.7	6.9
	Both	48	680	3.3	2.3	5.9	6.4	9.8	7.6	17.5	14.4	2.6	4.7	7.9	6.5

Significance: * $0.05 < P < 0.1$, ** $P < 0.025$.

Table 16. Stool parasitology and average diarrheal disease prevalence of malnourished and wellnourished children by medical care facility

STUDY GROUP	MEDICAL CARE FACILITY	No.	With Stool Parasites				Without Stool Parasites			
					Diar.Dis.Prev.*				Diar.Dis.Prev.*	
			#	%	Av.%	S.D.	#	%	Av.%	S.D.
Malnourished	Present	20	8	40	16.7	7.3	12	60	9.3	7.7
	Absent	4	3	75	7.6	6.6	1	25	8.5	-
	Both	24	11	46	14.2	8.0	13	54	9.3	7.4
Wellnourished	Present	11	6	55	9.7	6.5	5	45	5.6	5.3
	Absent	13	7	54	10.5	7.2	6	46	6.1	9.1
	Both	24	13	54	10.1	6.6	11	46	5.9	7.0
All	Present	31	14	45	13.7	7.6	17	55	8.2	7.2
	Absent	17	10	59	9.7	6.8	7	41	6.5	8.2
	Both	48	24	50	12.0	7.4	24	50	7.8	7.3

Significance: t for diarrheal disease prevalence with and without stool parasites = 1.96; P < 0.06 χ^2; for stool parasites in wellnourished and malnourished = 0.53; P = non significant.

* Diarrheal disease prevalence.

Table 17. Average developmental score and quotients by nutritional status

Age (months)	Nutritional Status	No.	Average Developmental Score		Average Developmental Quotients		"t"	P
			Score	S.D.	D.Q.	S.D.		
6 - 15	Malnourished	4	95	29.9	92	17.7	0.51	N.S.
	Wellnourished	2	59	0.0	86	17.7		
16 - 25	Malnourished	4	129	13.8	84	11.3	2.54	<.05
	Wellnourished	5	149	25.3	108	17.0		
26 - 35	Malnourished	14	154	23.7	89	13.8	2.85	<.01
	Wellnourished	18	172	9.1	100	4.9		
ALL	Malnourished	22			89	13.4	3.22	<.005
	Wellnourished	25			101	10.5		

In Table 16 the degree of infestations with stool parasites, almost exclusively Giardia lamblia, is not significantly different between the well-nourished and underweight groups. However, children with stool parasites were found to have a consistently higher diarrheal disease prevalence, than those without. This difference was somewhat significant (t = 1.96; P = 0.06), suggesting that the presence of parasites increases diarrheal disease prevalence.

Table 17 summarizes results of psychomotor testing. The Developmental Quotient (D. Q.) for each child was determined by dividing the child's achieved total score by the median score for all children of the given age. The difference in D. Q. between underweight and well-nourished children at 6 to 15 months of age was not statistically signifi-

Table 18. Developmental quotients by maternal care and nutritional status

Maternal Care Index	Nutritional Status								
	Wellnourished			Malnourished			All		
	No	D.Q.	S.D.	No.	D.Q.	S.D.	No.	D.Q.	S.D.
Wellcared	22	101.2 #	10.9	9	91.4 #	13.4	31	98.4 *	12.4
Neglected	3	95.0	3.6	13	87.5	13.6	16	88.9 *	12.6
ALL	25	100.5 **	10.5	22	89 **	13.4	47	95.2	13.1

** P = < 0.005; * P = < 0.025; P = < 0.10.

Table 19. Collective morbidity prevalence by levels of mother care

MATERNAL CARE STATUS	N	EYE INFECTION			SKIN INFECTION			FEVER			URTI			DIARRHEA		
		$\bar{X}$	S.D.	P	$\bar{X}$	S.D.	P	$\bar{X}$	S.D.	P	$\bar{X}$	S.D.	P	$\bar{X}$	S.D.	P
Well cared	31	6.9	5.73	<.05	4.5	4.98	ns	3.1	2.25	ns	15.0	12.6	ns	10.4	8.27	ns
Neglected	16	11.2	6.83		7.9	8.44		3.4	1.97		17.6	12.2		8.4	6.58	
All	47	8.4	6.46		5.7	6.45		3.2	2.15		15.9	12.4		9.7	7.75	

cant. Differences between the two groups became increasingly significant with increasing age. All ages combined, the underweight group of children had a significant lower D. Q.

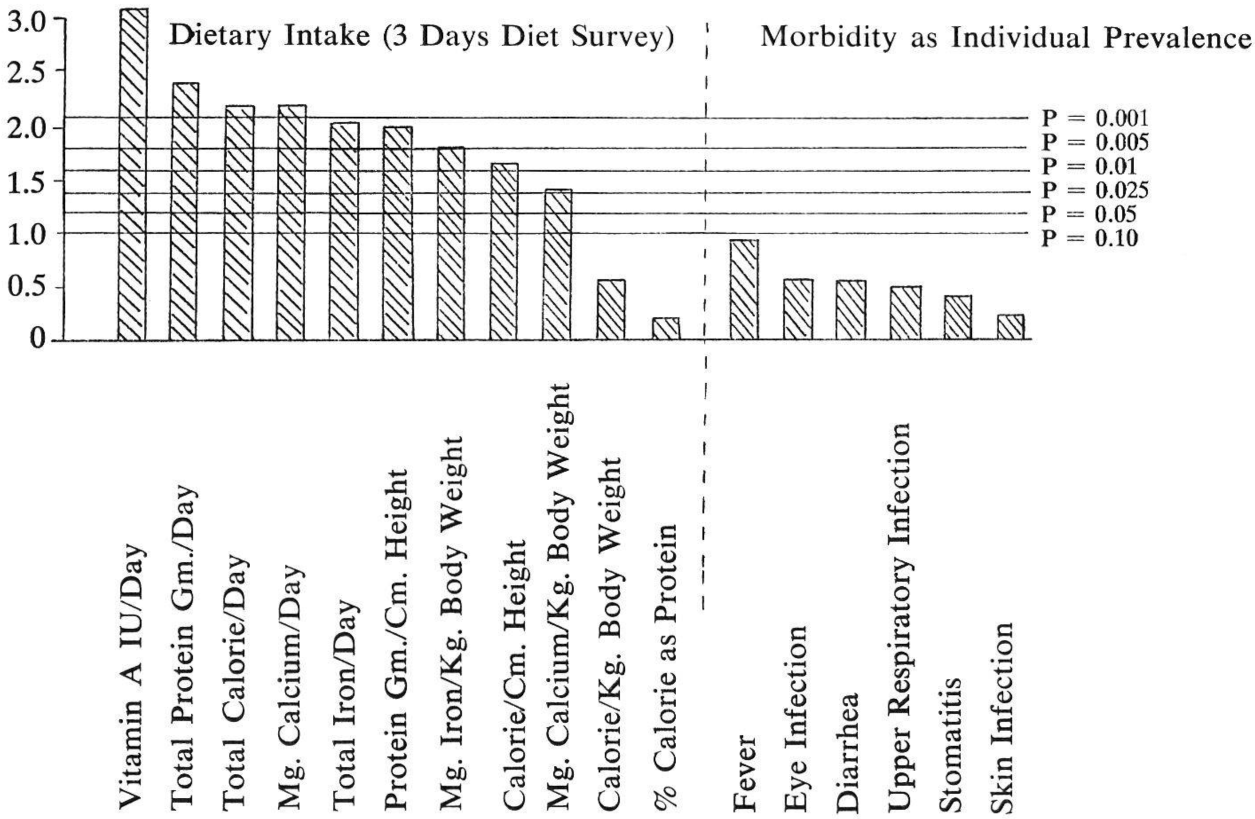
In Table 18 the influence of maternal care on psychomotor development is given. The D. Q. of neglected children was significantly lower than that of the well cared for ones irrespective of their nutritional status. Differences in D. Q. between the well cared and neglected within each nutritional classification, did not reach statistical significance.

Table 19 shows the effect of maternal care on the children's morbidity experience. Except for diarrhea, neglected children tend to show higher morbidity prevalence. The difference was statistically significant for eye infection ($P < 0.05$).

There were no significant differences in the responses between mothers of well-nourished and underweight children to the six questions on knowledge of child nutrition.

In Figures 1, 2 and 3 significance levels of various sets of variables are presented graphically. Thus, for dietary intake variables, vitamin A, total protein, calorie, calcium intakes are highly significantly ($P = 0.001$) different between the two groups; their caloric intake per kilogram body weight and the proportion of calories derived from

Fig. 1. Significance levels for different variables between the two study groups.



X axis = Variables used as parameters for comparison.
Y axis = Left hand: observed "t"/"t" value for given sample size at which P = 0.1; right hand: significance level of observed "t".

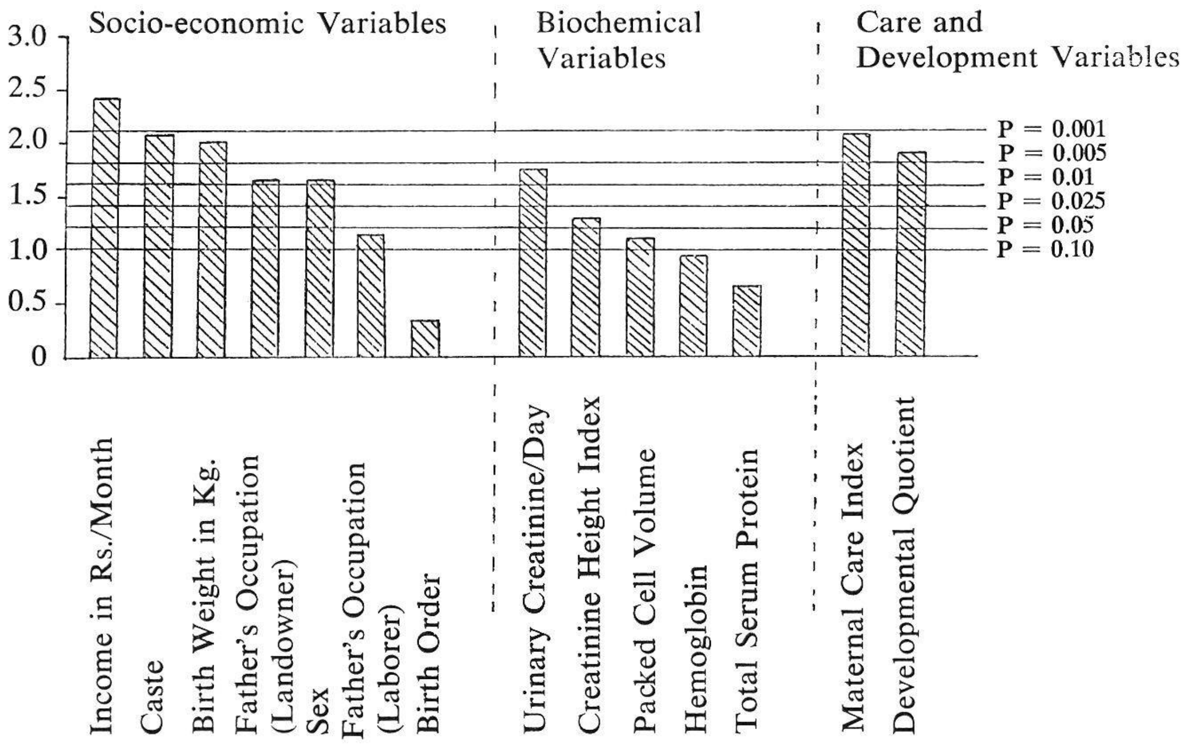
protein on the other hand do not differ to any significant extent. The remaining bargraphs can be interpreted in a similar way.

B. Discriminant Analysis

Using the stepwise discriminant analysis the following variables in Set 1 and listed in descending order of their F values proved to reach maximum discrimination between the underweight and well-nourished children. 1) Vitamin A intake (F 1/47 = 38.2); 2) Parental income (F 1/46 = 6.5); 3) Eye infection prevalence (F 1/45 = 2.7); 4) Maternal care index (F 1/44 = 3.0); 5) Percent calories as protein (F 1/43 = 2.2); 6) Diarrheal disease prevalence (F 1/42 = 1.7); 7) Caste (F 1/41 = 1.7); and 8) Birth order (F 1/40 = 1.9). Stepwise introduction of these variables resulted in correct classification of 21 of 25 (85%) of the well-nourished and 23 of 24 (96%) of the underweight children.

Using Set 2, maximal classification was achieved with the following two variables, ranked in decreasing order of their F values:caste

Fig. 2. Significance levels for different variables between the two study groups.

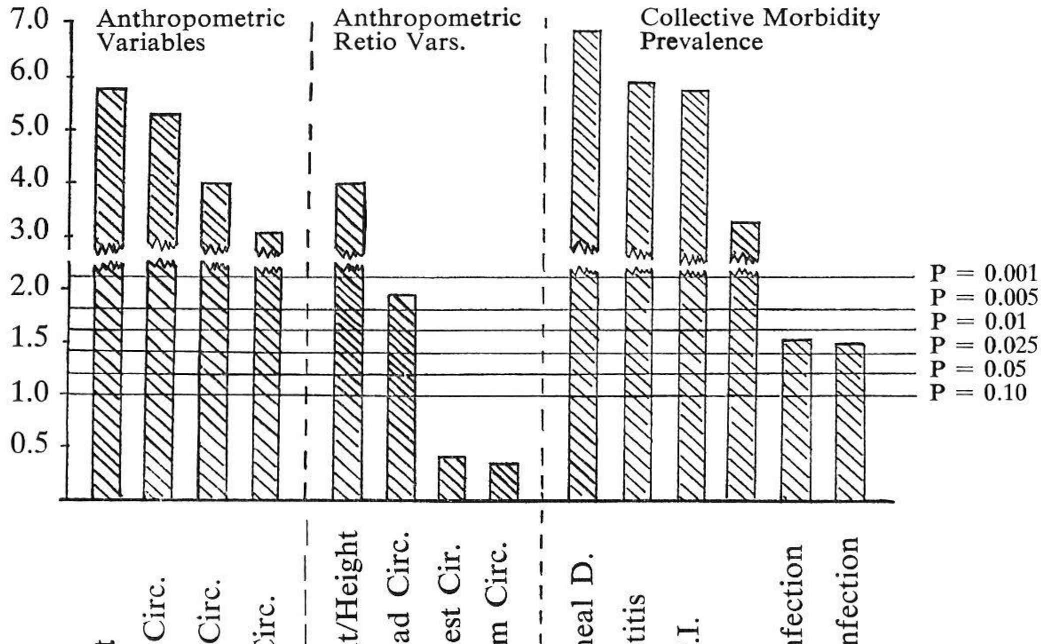


X axis = Variables used as parameters for comparison.

Y axis = Left hand: observed "t" value/"t" value for given sample size at which P is 0.1; right hand: significance level of observed "t".

DQ = Psychomotor score of study child/median score for given age.

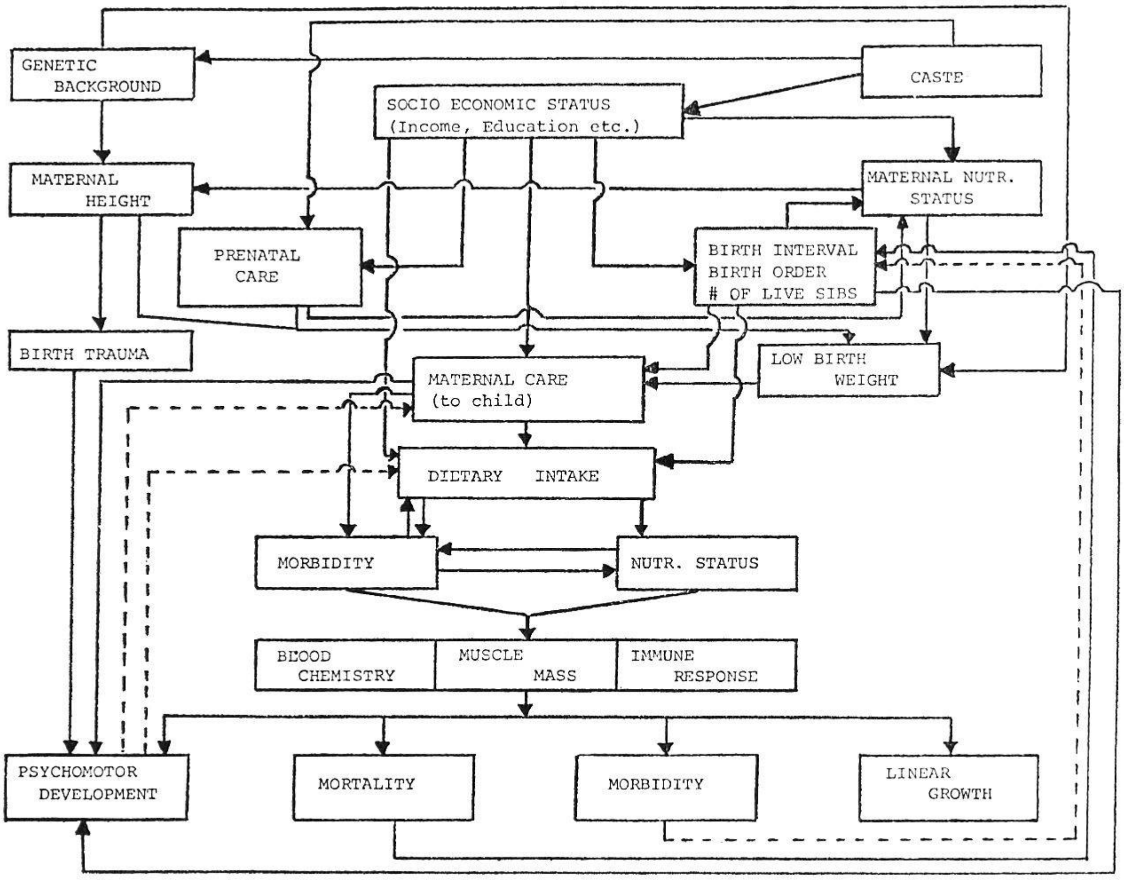
Fig. 3. Significance levels for different variables between the two study groups.



X axis: Variables used as parameters for comparison.

Y axis: Left hand: observed "t" value for given sample size at which P = 0.10; right hand: significance level of observed "t".

Fig. 4. Interactions of etiological determinants and effects of protein calorie malnutrition.



(F 1/47 = 16.2) and parental income (F 1/46 = 1.8). Introduction of the remaining variables did not achieve better separation. Eighty percent of well-nourished and 79% of the underweight were correctly identified.

IV. Discussion

The main objective of this study was to identify major and contributory etiological determinants of protein calorie malnutrition operative in the well circumscribed child community of the Narangwal Nutrition Project. This, we hoped, would at the same time give us some idea of the interrelationship between social, demographic, economic, dietary and cultural variables in their effect on the health status of the Punjabi preschool child. Secondly, we wanted to find a means of recognizing the "child at risk" of becoming malnourished before it had actually started its nutritional decline, which as we had shown in our parent study was not only extremely difficult to reverse but was fraught with exhorbitant risks to its life (R.H.R.C. Report 1972).

To accomplish our objective we intentionally selected children who were recognized as "malnourished" on paper only, in that their weight gain over the preceding four months had dropped to 70% or less of the 50th percentile of the Boston reference population. Childen below 70% of the Boston Standard constitute anywhere between 20% and 50% of the child population of rural Punjab, exact figure depending on the time of season, the socioeconomic status of a village or district and the outcome of the harvest in any given year. It is this group that makes up the majority of child deaths, yet, most studies we reviewed prior to undertaking this investigation focussed on the socio-cultural-clinical background of the severely malnourished, hospitalized marasmus or kwashiorkor child. These are usually quite unrepresentative of the general child community in that they probably represent not more than two percent of the preschool child population and constitute the end product of a series of extreme conditions that do not apply to children in general.

By choosing only weaned children we undoubtedly introduced a bias in our lowest age groups (below 18 months) which may be reflected in the fact that we only had two well-nourished but four malnourished children in this age range. Socio-cultural differences in this age range may therefore not reflect the norm. Since, however, only six children were within this age range, whatever bias was introduced, should only marginally deflect the validity of our conclusions.

Children were selected on the basis of their weight per given age. All additional anthropometric measurements were done after the two groups had been defined. Assuming that the anthropometric differences were not genetically determined, the fact that height, head, chest and arm circumferences were significantly lower in all age groups of the underweight population, implies both a chronic rather than short term nutritional deprivation and stunting of their overall physical growth.

From the anthropometric ratios and under the limitation of the small sample size one can make several suggestions as to the differential growth of specific body structures. Thus, it seems that thoracic growth, as measured by chest circumference and increase in the peripheral muscle mass, as measured by arm circumference, are about equiproportional to linear growth in the two groups. The fact that both the urinary creatinine excretion and creatinine height indices were significantly lower among the malnourished of most age groups suggests that total muscle mass is, however, reduced. The ratio height to head circumference, on the other hand, increased to a significantly lesser extent with increasing age among the malnourished than among the well-nourished suggesting that growth in head circumference, though reduced, is less affected by the status of undernutrition than is height. One might postulate that brain growth as measured by change in head circumference in the malnourished may be relatively favoured at the expense of other organs. This finding, should be verified on a considerably larger child population.

Overall, body weight per centimeter of height among the malnourished lags behind that of the well-nourished attesting to their proportionately reduced fat and, perhaps organ and muscle mass.

Haemoglobin levels are uniformly low in both malnourished and well-nourished groups; lower, in fact, than shown in a survey on all nutrition supplemented children (R.H.R.C. Report 1972), despite a seemingly adequate intake (WHO, 1974). This may have several reasons: for one, it has been shown that considerable number of infants get sensitized to whole cow's milk and as a result suffer from gastrointestinal bleeding leading to iron deficiency anemia (WILSON et al., 1962). Buffalo milk may similarly cause blood loss although to our knowledge this has never been shown. Two, the observed iron intakes carry a decided seasonal bias. As all diet survey work was being carried out during the winter months, iron intakes, because of the abundance of mustard greens and raw sugar in the diet during this time, are unusually high. Also, it has been suggested that subclinical malabsorption may be responsible for selective nutritional deficiencies. One investigator working in the Punjab found in a group of 18 hospitalized adult patients, 13 with subclinical steatorrhea and, in another group of nonpregnant adults, 67 of 185 excreting an average of 13 grams of fat per day as determined on 24 hour stool samples (COWAN et al., 1968; COWAN, 1972).

Total serum protein concentration in both groups are considerably higher than in a Caucasian reference population (MCCAMMON, 1970). We assume this to be due to an increase in the immunoglobulin fraction resulting from the usually prevailing high infectious and parasitic disease loads, from early age on. High levels of IgG and IgM, occasionally IgA have been reported in other child communities of the developing world (GOLUBJATNIKOV et al., 1972; NEUMANN et al., 1975).

Daily dietary intakes of the underweight group show significantly lower values for all of the examined nutrients. Whereas the protein intakes among the underweight seem more than adequate according to the recent WHO nutritional guidelines (WHO, 1974), the calorie intakes are about 35% less than the recommended minimum. This finding agrees with that of a survey in South India where the calorie gap had also been found to be the limiting factor for adequate growth (GOPALAN et al., 1973). Differences in protein intakes between the two groups are proportionally larger, however than calorie intakes; suggesting that both calorie and protein intakes were deficient in the underweight children.

Dietary deficiency appears to be the single most important factor responsible for their overall lower nutritional status. Inadequacy of dietary intake, both qualitative and quantitative may have been due to a number of reasons, the most frequent being the economic status of the family, as shown by the fact that there was no significant difference in the income levels between the parents of underweight children of high and low castes. The nonfarming high caste parents of the underweight and well-nourished children did not show any marked difference in their occupational patterns, but their mean incomes were significantly different. The fact that the income levels between the well-nourished of high and low caste are significantly different may be due to an ability of low caste families to utilize their limited resources more efficiently. Maldistribution of food within the family may have been a second important reason as brought out by the differential in maternal care between the two groups, especially among the higher caste. Equally important, if not more in the causation of malnutrition, appear to be the birth weight. It may have influenced the future nutritional status through two main mechanisms. One, the quantity of food available to the average rural family in this area may be adequate to sustain normal development in a healthy neonate but falls short for the premature or low birth weight child who not only has problems sustaining his genetic growth potential but needs to overcome the weight handicap he was born with. Secondly, the mother of a low birth weight child may feel that it is probably not going to survive anyway and, instead of wasting her efforts on a "lost cause" may be encouraged to have another, presumably sturdier child. Thus of the 8 children with birth weight under 2500 grams, only 2 were considered well cared for.

Although more malnourished children (29%) were of 4th or higher birth order and had a higher percentage of 4 or more living siblings (16%) than well-nourished ones (25% and 4% respectively), these differences did not reach statistical significance. The figures suggest, though, that scarcity of food because of presence of many members in a joint family and perhaps resultant ill distribution may have been contributing factors; especially since caste and sex showed such clear correlation with nutritional status. For caste it was most likely because of the associated lower income; for sex, because of the very strong preference for the male child in the Punjabi community.

Morbidity prevalence among the two groups, when looked at as collective totals are significantly different from each other. This becomes rather important when one looks at child communities of differing nutritional composition rather than the individual for the purpose of planning health care services.

When looked at from the individual child's point of view, differences were only marginally significant for fever and diarrheal disease prevalence, where, in both cases, the well-nourished showed lower rates. The almost uniformly higher prevalence rates in villages with than without medical care facilities probably reflects better reporting and observation by the mother and resident health worker respectively than a real situation. This probably because of their mutual understanding that treatment would be instituted in medical care-provided villages whereas little beyond reassurance could be given in those without.

Surprisingly there was no difference in the stool parasitology between the two groups. This was subsequently confirmed in a larger study involving more than 150 children from the same group of villages. (In more than 85% of cases Giardia lamblia was the only parasite found among the positives.) Not surprisingly though, diarrheal disease prevalence showed an almost significant association ($P = 0.06$) with parasitic infestation. Thus, it seems that in this area parasitic infestation can probably be ruled out as an important contributory cause to malnutrition, but may be significant in the etiology of diarrheal diseases in the child population of the nutrition project. It is difficult to imagine why past eye infection prevalence in villages without an infectious disease control program should be significantly higher on an individual basis in the well-nourished than in the underweight child. Differential maternal care provides only a partial explanation. Thus, the one neglected child among the well-nourished group had experienced an eye infection prevalence of 13% of its time under observation as compared to a mean prevalence of less than 6% of the remaining children in the same group. However, even after correction for this one child, eye infection prevalence among the well-nourished remains significantly ($P = 0.05$) higher.

One might assume that the level of morbidity underreporting by mothers of underweight children is higher than those of well-nourished ones. This, however, has not been shown by our data. Thus, 50% of underweight neglected and 73% of the underweight well cared for had a prevalence of less than the mean. Overall, it seems that the neglected children have higher mean individual illness prevalence rates. For eye and skin infections, illness frequently protracted because of maternal neglect, well cared for children showed a 40% lower prevalence rate. The observed differential was statistically significant ($P = 0.05$) for eye infection but not for any of the other illnesses.

The level of mother care provided seems to be an important contributory determinant of not only the nutritional status but the overall wellbeing of the child. As in the case of low birth weight, we may assume a similar interrelationship between nutritional status and received care to hold true. Thus, in a parallel study on child mortality (R.H.R.C. Report 1975), it was found that mothers of severely malnourished children sought medical care significantly later for the terminal illness of their children than those of borderline or well-nourished ones.

Contrary to our assumption that a retarded psychomotor development influences the level of nutritive care and thus may bring about undernutrition, our data seems to indicate the reverse to hold true. This is brought out by the observation that levels of psychomotor achievement between underweight and well-nourished control children did not differ to any significant extent below 15 months of age but became progressively larger with increasing age. Interestingly, underweight children that were also neglected achieved the lowest, well-cared-for well-nourished the highest and well cared for underweight and neglected well-nourished children, intermediate scores, suggesting an additive and, possibly synergistic effect of maternal care and state of nutrition on psychomotor development.

The close interrelationship of all variables examined was brought out by the discriminate analysis. Thus, vitamin A intake because of its vast differential between the two groups singly achieved the highest degree of differentiation between the two groups. This does not mean that vitamin A was the limiting factor for normal growth, even though its intake in the underweight was almost 33% below the intake recommended in a recent WHO publication (WHO, 1974). Rather, the vitamin A intake in the underweight may have acted as a proxy variable for a combination of other variables that tend to be associated with malnutrition, such as low caste, female sex, income below a certain level, inadequate quality and quantity of dietary intake and perhaps a higher level of morbidity experience. Clinically none of the underweight children in this study showed overt signs of vitamin A deficiency. Judging from our clinical experience with children in the Narangwal Project, in general, vitamin A deficiency signs, though occassionally found, were rather the exception in this area. This concept of proxy variables is well illustrated by the rapid decline of the F values of otherwise highly significant variables, following introduction of vitamin A as a variable into the equation and also by the second set of variables introduced into the stepwise discriminant analysis, where in the absence of vitamin A as one of the variables, caste ranks before parental income. Thus, caste as well as several attributes of caste affiliation reflected themselves in a given level of vitamin A intake and caste as a single variable became less important within the group of variables. Once vitamin A was no longer used, these "attributes" reverted to caste and its discriminant power consequently rose. The discriminate analysis, though unable to define variables in order of their etiological significance, selects the minimum number of those necessary that best describe and separate the two groups. As such it constitutes an excellent tool for the determination of the most important variables that need to be included in a survey of children at risk of becoming malnourished. Etiologically important variables, that need characterization for the purpose of intervention programme planning, could subsequently be sorted out through other statistical means, such as the path analysis.

In conclusion we would like to highlight the fact that the group of underweight children though selected entirely on the basis of being below an arbitrarily defined standard weight for age and according to the community they belonged to having none of the physical characteristics of sick children nevertheless showed significantly less favourable indices of growth, illness experience, home environment and generally speaking quality of life than the well-nourished counterparts. Yet these children probably make up the majority of the child population of Rural India.

Using our results, we have attempted to provide a model (Figure 4) of both the etiological variables and consequences of malnutrition in the Narangwal study villages. Several assumptions were made where we lacked data or where our results remained inconclusive. For instance, we assumed that maternal malnutrition leads to a higher percentage of low birth weight infants, mainly because we had found previously, that prematurity rates were significantly higher, maternal heights significantly lower among the lower caste groups (R.H.R.C. Report 1972a).

The model, we hope, will bring out the complexity of the etiology of malnutrition and hopefully impress on the health planners that malnutrition in rural India, today, is not amenable to simplistic intervention programmes such as administration of food on a mass scale to the target population but demands the cooperation of many disciplines such as economics, education, agriculture, overall community development, and health.

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