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Nutritional assessment of Oraons of West Bengal: a comparison between biochemical and anthropometric methods

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ABSTRACT: Comprehensive nutritional assessment is the basis of nutritional diagnosis and necessary to identify the individual or the population at a risk of dietary deficiencies. However, there is no specific and confirmatory method to measure nutritional status. Present study tried to find out the efficacy of two nutritional assessment method (1) biochemical test like Total serum protein (TSP) and (2) anthropological measurements like body mass index (BMI) and mid-upper-arm-circumference (MUAC). Later, three methods were tested and compared for the strength of assessing the nutritional status. Study was conducted among 198 adult Oraon, 84 male, 114 female individuals of Madarihat and Falakata police station area, Alipurduar district, West Bengal. Selected blood parameters such as total serum protein (TSP), serum albumin and haemoglobin and anthropometric measurements (height, weight, mid-upper arm circumference, waist circumference, hip circumference, calf circumference, biceps skinfold, triceps skinfold, and calf skinfold) were obtained following standard instruments and protocols. Nutritional status of all individuals was assessed by TSP, BMI and MUAC classification methods. Comparison between/among three classification methods (TSP, BMI and MUAC) was done and discriminant function analysis was adopted to find out the percentage of correct classification by each methods. It was found that prevalence of undernutrition using TSP classification was 38.1% male and 43.0% female; using BMI was 34.5% male and 53.5% female; using MUAC was 45.2% male and 64.9% female. Discriminant function analysis showed that BMI (97.0%) had the highest capability of correct classification followed by MUAC (84.80%) and TSP (63.60%). Results indicate that however, TSP is an objective way of nutritional assessment, but BMI had the highest capability of correct classification of nutritional status. It may be pointed out that the evaluation with TSP was expensive and invasive whereas BMI is non-expensive and completely a non-invasive way of evaluation. Therefore, BMI may widely be used for nutritional assessment.

KEY WORDS: undernutrition, total serum protein, body mass index, mid-upper arm circumference, discriminant function analysis

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Introduction

Undernutrition is one of the important problems of health and illness, affecting mostly the women, children and elderly individuals of developing countries, including India (WHO 2009; UNICEF et al. 2015; FAO 2015). Several previous studies have reported the cause and direct/indirect effects of undernutrition on human health (Dickson et al. 2000; Muller et al. 2005; FAO 2006; Maleta 2006; Martins et al. 2011). However, there are no accurate diagnostic methods, because of its complex etiology but several screening methods have been developed to determine the nutritional status of individuals and at population level, such as: (i) assessment of clinical signs and symptoms for impaired nutrition, (ii) measurement of dietary intake, (iii) biochemical measurements of body fluids and (iv) anthropometric measurements of body composition (WHO 1963; Woodruff et al. 2000; Gibson 2005; Elmadfa et al. 2014; Srivastava et al. 2014).

Out of all the methods, biochemical analysis of body fluid is considered to be the objective method to determine nutritional status. It uses laboratory analyses of serum protein, serum micronutrient level, serum lipids, and immunological assay in order to assess general nutritional status that helps to identify specific nutritional deficiencies of vitamins, minerals or protein (Jacques 1993; Bharadwaj et al. 2016). Essentially, biochemical indicators are helpful in detecting secondary undernutrition caused due to some clinical abnormalities (Woods 1982; Sahyun 1988; Roongpisuthipong et al. 2001; Knox 2003; Forga 2016). Biochemical analyses are very expensive as well as invasive method, needs laboratory set-up and professional people. Therefore, population based screening through biochemical parameters for undernutrition is quite impossible.

Whereas anthropometry has a long tradition of assessing nutritional and health condition of adults. The measurements are highly sensitive to the broad spectrum of nutritional status and are able to detect nutritional deficiency even before the appearance of clinical signs. This method provides detailed information on the different components of body structure, especially muscular and fat components (Bharati et al. 2007; Misra et al. 2001) and is widely used in population based studies as this is an inexpensive and non-invasive method.

Methodologies used for nutritional assessment vary across different study groups and settings (urban or rural). Assessment in rural population, usually rely on the anthropometric surveys (Dettwyler 1992; Biswal et al. 2014; Pal et al. 2017; Ibuaku et al. 2018). Weight, height measurement and computation of body mass index is the primary and widely used nutritional assessment tool (Khongsdier 2002; Lee et al. 2003; Shetty et al. 1994). Anthropometric measurement of biceps and triceps skinfold thicknesses and mid upper arm circumference have also been used in several studies to estimate muscle and fat mass and thereby determining nutritional status (Falciglia et al. 1988; WHO 1995; Kumar et al. 2000; Moreno et al. 2003; Garofolo et al. 2005). Waist circumference and waist-hip ratio have also been used for nutritional assessment (Dutta Banik 2009; De 2017). Some community studies on nutritional assessment were based on the dietary surveys (Bolton et al. 1991; Hu et al. 1999; Lee et al. 2002; Schatzkin et al. 2003; Gibson 2005; Shim et al. 2014). The biochemical assessment of nutritional status by blood or urine parameters were primarily carried out in epidemiological surveys (Haluzik et al. 1999; Raguso et al. 2003; Fuhrman et al. 2004; Prenner et al. 2014; Lee et al. 2015). However, it is expensive and is not always feasible in field situation.

The present study was carried out among one of the marginal groups (Oraon) of West Bengal. The marginal populations are primarily under-privileged group living in a harsh condition. They have low level of literacy, economically deprived and are unaffected by the developmental process undergoing in the country. They are highly vulnerable to diseases with high degree of malnutrition, morbidity and mortality (Balgir 2004). Poor nutritional condition associated with low hemoglobin, low calorie as well as low protein consumption and diet deficient in vitamins and minerals make them undernourished and susceptible to various diseases such as tuberculosis, malaria, gastrointestinal diseases, filariasis, measles, tetanus, whooping cough, skin diseases (scabies), etc. (Balgir 2006). Thus creates a serious burden for the society and nation at large. So, proper evaluation of the nutritional status of the population is necessary for the betterment of this group and also for the society.

In view of the above, present study was carried out among the Oraons, one of the marginal groups of West Bengal, to assess the nutritional status. Nutritional assessment was performed with two types of nutritional assessment tools: (1) biochemical marker (Total serum protein) and (2) anthropometric measurements (Body mass index and Mid upper arm circumference). The objective was to compare between two methods of nutritional assessment, i.e. biochemical against anthropometric measurements and thereby to find out more effective tool that can be used in population based studies for nutritional assessment.

Materials and Methods

Study population

Data on blood specimens (for laboratory analysis of different parameters) and anthropometric measurements were collected as part of an ongoing bio-medical project from Oraon labourers. Oraons are one of the marginal populations of India, they call themselves as '*Kurukh*', speak 'Sadri', although they were Dravidian speaking group. After migrating from Chotanagpur plateau (presently Jharkhand) to the Alipurduar district as tea garden labourer, some of them cleared jungles and became settled as agriculturists and mostly live in a harsh condition. The present study was carried out among the labourers residing in five villages (Madhya Rangalibajna, Uttar Rangalibajna, Champaguri, Manipur and Nabipur) under Madarihat police station area and one tea garden (Tasati Tea Estate) under Falakata police station area of Alipurduar district of West Bengal, India. The study area has been chosen on the basis of prior rapport and operational convenience.

Data comprises 198 (Male 84, Female 114) Oraon adults from two occupational subgroups, one group engaged as agriculture labourer and other group as tea garden labourer, both having similar socio-economic status and living condition (both live in the Himalayan foothill region [Dooars] of West Bengal). The study was performed with the prior consent of the participants. No statistical sampling was adopted, because any kind of selection within the population would have raised suspicion in the minds of the people studied, regarding the purpose of the study. However, the participants were chosen without any conscious bias; actually the participants who could be persuaded to participate in the study and volunteered themselves for participation in the study were included in the sample. The present study considered only Oraon groups to eliminate ethnic/genetic effect on nutritional status.

The study was conducted after prior approval from the Ethical Committee for Protection of Research Risks to Human, Indian Statistical Institute, Kolkata.

Blood Parameter Measurement

Analysis of total serum protein (TSP), serum albumin (SA) and haemoglobin (Hb) from collected blood specimens were determined. Blood was drawn from medial cubital vein of upper limb by vein puncture method with the help of trained professional. Collected samples were carried out in a local laboratory, 'Astha Diagnostic Centre' at Birpara, Alipurduar, for analysis. TSP was measured by Biuret method (Tietz 1994), serum albumin was measured by BCG (Bromocresol Green) method (Doumas et al. 1971) and haemoglobin was measured by Cyanohaemoglobin method (van Kampen et al. 1961). In each case, the intensity of the colour of the reagent (formed in reaction) is directly proportional to the amount of total protein/albumin/haemoglobin present in the sample. Standard values were of each of the blood parameters were considered as reference.

Anthropometric Measurements

Anthropometric measurements from 198 adult individuals were obtained following standard protocol and instruments (Weiner and Lourie 1981). Length measurement i.e. height (Ht) was measured (±0.1 cm) by Martin's anthropometric rod (GPM, Switzerland). Weight (Wt) was measured (±0.1 kg) with an electronic scale (Omron HBF-375 Karada Scan, Japan). All the circumferences i.e. mid-upper arm (MUAC), waist (WC), hip (HC) and calf (CC), chest circumference normal (CN) were measured by measuring tape (±0.1 cm). Skinfold thicknesses i.e. biceps (BSK), triceps (TSK) and calf (CSK), sub-scapular skinfold (SBSK), supra-iliac skinfold (SISK) were measured by Holtain skinfold caliper (±0.2 mm). All the diameters i.e. bi-epicondylar diameter of humerus (BDH) and femur (BDF), bi-acromial (BAD) and bi-iliac (BID) diameters were measured (±0.1 cm) by spreading caliper. Further, body mass index (BMI) was calculated using the formula:

$$BMI = \text{Weight in kg}/(\text{Height in meter})^2.$$

All measurements were taken by single investigator.

Nutritional Status Classification

The nutritional status of the study population was determined by TSP level (Killingsworth 1979), as well as two conventionally used anthropometric methods i.e. BMI (WHO 2004) and MUAC (Ferro-Luzzi et al. 1996). Classification for nutritional assessment has been described in Table 1.

As the mean BMI of the studied sample was 19.16 for male and 18.53 for female, and mean MUAC was 22.99 cm for male and 20.9 cm for female, so for the purpose of analysis, nutritional status was classified into two categories (a) normal and (b) undernutrition.

Table 1. Criteria for classification of nutritional status

Nutritional status	TSP† (gm/dl)	BMI*	MUAC# (cm)	
			Male	Female
Undernutrition	<6.00	<18.50	<23.00	<22.00
Normal	6.00–8.00	18.50–24.99	≥23.00	≥22.00
Overweight	–	≥25.00	–	

†TSP: Total serum protein; *BMI: Body mass index; #MUAC: Mid-upper arm circumference.

Statistical Analysis

Descriptive statistics of all the variables and discriminant function analysis was performed. All the statistical analysis was performed using PASW, version 18.0 (SPSS Inc., Chicago, IL, USA).

Discriminant function analysis

Discriminant function analysis is primarily a multivariate test to observe the differences between groups. This is the reverse of MANOVA, where independent variables are grouped and dependent variables are continuous predictors. But here, the independent variables are the continuous predictors and dependent variables are the groups (Klecka 1980). In the present study, nutritional status (having two groups – normal and undernutrition) according to TSP, BMI and MUAC was considered as dependent variable. All other biochemical parameters and anthropometric measurements were considered as independent variables. Further, stepweise discriminant analysis was carried out to determine the best combinations of the independent variables.

The analysis can be splited into 2-steps – (a) testing significance of a set of discriminant functions, and, (b) classification. In the study, second step of the analysis was used for the classification of nutritional status in view of the equations created in the analysis. Computationally a canonical correlation analysis was performed and to determine the successive functions and canonical roots. Classification was then feasible from the canonical functions. Individuals were classified in the groups in which they had the highest classification scores (Pal et al. 2014). This analysis further provided a percentage of overall correct classification.

Results

Table 2 describes the descriptive statistics of age, selected anthropometric traits, blood parameters and body mass index of the study population of either sex. It was observed that the mean values of all the variables were higher in males in respect to females (except skinfold thicknesses).

Table 3 depicts the frequencies and percentages of normal and undernourished category, on the classification criteria of TSP, BMI and MUAC categories. TSP classified 38.1% males and 43.0% females in undernutrition category. BMI classified 34.5% males and 53.5% females in undernutrition category. Whereas MUAC classified 45.2% male and 64.9% female in undernutrition category. Therefore, total frequency of undernutrition was highest according to MUAC classification (56.6%) and lowest according to TSP classification (40.9%).

Table 4 describes the descriptive statistics and mean differences of age and anthropometric variables between the two nutritional groups, i.e. normal and undernutrition according to TSP, BMI and MUAC classifications. According to TSP classification, the mean values of MUAC, CC and Hb were significantly different between two nutritional groups. Whereas, according to the BMI and MUAC classifications, the mean values of Ht. (only

Table 2. Descriptive statistics of age and anthropometric measurements of adult individuals in either sex

Variables (Abbreviation)	Male (n= 84)		Female (n=114)		Total (n=198)	
	Mean	SD	Mean	SD	Mean	SD
Age (Age, years)	40.83	15.56	38.97	13.32	39.76	14.31
Height (Ht , cm)	161.74	5.62	151.06	4.88	155.59	7.42
Weight (Wt, kg)	50.17	6.43	42.35	6.27	45.67	7.41
Circumferences						
Mid-upper arm circumference (MUAC, cm)	22.99	2.86	20.9	3.64	21.79	3.48
Waist circumference (WC, cm)	71.73	5.82	70.46	8.29	71.00	7.35
Hip circumference (HC, cm)	80.96	5.02	79.41	8.71	80.07	7.40
Calf circumference (CC, cm)	29.74	2.91	27.33	4.14	28.35	3.85
Chest circumference normal (CN, cm)	82.06	5.50	71.34	5.10	75.89	7.48
Skinfold thicknesses						
Biceps skinfold (BSK, mm)	2.73	0.9	3.8	2.13	3.35	1.80
Triceps skinfold (TSK, mm)	4.93	1.96	8.1	4.17	6.75	3.75
Calf skinfold (CSK, mm)	5.37	3.05	8.64	4.59	7.25	4.32
Sub-scapular skinfold (SBSK, mm)	7.78	2.43	8.98	4.22	8.47	3.61
Supra-iliac skinfold (SISK, mm)	3.71	1.12	5.99	9.42	5.02	7.26
Diameters						
Bi-epicondylar diameter humerus (BDH, cm)	6.44	0.43	5.69	0.45	6.01	0.58
Bi-epicondylar diameter femur (BDF, cm)	8.60	0.54	8.19	2.59	8.36	2.00
Bi-acromial diameter (BAD, cm)	32.73	2.44	29.46	2.09	30.85	2.77
Bi-iliac diameter (BIA, cm)	22.29	1.96	22.34	1.81	22.32	1.87
Blood parameters						
Haemoglobin (HB, gm/dl)	11.38	2.08	10.09	1.53	10.64	1.89
Total serum protein (TSP, gm/dl)	7.23	0.68	7.19	0.71	7.21	0.70
Serum albumin (SA, gm/dl)	4.33	0.51	4.31	0.4	4.32	0.45
Index						
Body mass index (BMI, kg/m^2)	19.16	2.09	18.53	2.5	18.8	2.35

Table 3. Classification of nutritional status by TSP, BMI and MUAC of study group in either sex

	Classification categories	Male (n=84)		Female (n=114)		Total (n=198)	
		n	%	n	%	n	%
TSP classification	Normal (6 gm/dl-8 gm/dl)	52	61.9	65	57.0	117	59.1
	Undernutrition (<6 gm/dl)	32	38.1	49	43.0	81	40.9
BMI classification	Normal (18.50-24.99)	55	65.5	53	46.5	108	54.5
	Undernutrition (<18.50)	29	34.5	61	53.5	90	45.5
MUAC classification	Normal (>23.00 cm [M], >22.00 cm [F])	46	54.8	40	35.1	86	43.4
	Undernutrition (≤23.00 cm [M], ≤22.00 cm [F])	38	45.2	74	64.9	112	56.6

Table 4. Descriptive statistics of age and anthropometric variables of normal and undernourished groups according to TSP, BMI and MUAC classifications

Variables	TSP classification				BMI classification				MUAC classification			
	Normal (n=117) Mean±SD	Undernut. (n=81) Mean±SD	*t* df=196	*p*-value	Normal (n=108) Mean±SD	Undernut. (n=90) Mean±SD	*t* df=196	*p*-value	Normal (n=86) Mean±SD	Undernut. (n=112) Mean±SD	*t* df=196	*p*-value
Age	38.88±14.40	41.04±14.17	1.04	0.29	39.12±15.36	40.53±12.97	0.69	0.49	38.78±14.33	40.52±14.30	0.85	0.39
Ht	155.57±8.19	155.63±6.19	0.06	0.95	156.48±7.69	154.53±6.98	1.85	0.06	157.54±7.37	154.09±7.13	3.32	0.001
Wt	46.22±7.620	44.88±7.07	1.25	0.21	50.28±6.07	40.14±4.54	13.09	<0.001	51.29±6.10	41.35±5.07	12.52	<0.001
MUAC	22.39±2.92	20.92±4.03	2.99	0.003	23.59±3.10	19.63±2.58	9.65	<0.001				
WC	71.36±7.24	70.48±7.53	0.82	0.41	74.16±6.81	67.21±6.11	7.49	<0.001	74.86±6.82	68.04±6.32	7.27	<0.001
HC	80.32±8.45	79.70±5.56	0.59	0.56	82.39±8.69	77.27±3.98	5.15	<0.001	83.97±4.71	77.07±7.70	7.32	<0.001
CC	29.03±3.30	27.38±4.36	3.02	0.003	30.16±3.47	26.19±3.10	8.41	<0.001	30.62±2.75	26.61±3.67	8.46	<0.001
CN	76.40±7.62	75.15±7.24	1.15	0.25	79.68±6.88	71.43±5.42	9.26	<0.001	80.41±6.84	72.42±5.94	8.78	<0.001
BSK	3.38±1.63	3.30±2.03	0.29	0.77	3.91±2.14	2.67±0.90	5.16	<0.001	4.07±2.16	2.79±1.20	5.29	<0.001
TSK	6.76±3.40	6.74±4.22	0.03	0.97	7.77±4.28	5.54±2.51	4.35	<0.001	8.09±4.59	5.73±2.52	4.61	<0.001
CSK	7.40±4.24	7.04±4.45	0.58	0.56	8.29±4.50	6.01±3.75	3.81	<0.001	8.58±4.89	6.24±3.52	3.91	<0.001
SBSK	8.77±3.48	8.04±3.78	1.39	0.16	9.83±4.11	6.88±1.97	6.26	<0.001	10.25±4.36	7.11±2.08	6.69	<0.001
SISK	4.55±2.31	5.71±2.31	1.11	0.27	5.71±7.74	4.21±6.61	1.45	0.15	5.05±2.98	5.00±9.32	0.05	0.96
BDH	5.99±0.52	6.04±0.65	0.59	0.55	6.10±0.54	5.90±0.60	2.46	0.01	6.10±0.44	5.94±0.65	2.04	0.04
BDF	8.19±0.59	8.61±3.04	1.43	0.15	8.52±2.19	8.18±1.75	1.20	0.231	8.36±0.59	8.36±2.62	0.005	0.99
BAD	30.93±3.02	30.72±2.36	0.52	0.60	31.78±2.64	29.75±2.52	5.49	<0.001	32.09±2.59	29.90±2.52	5.99	<0.001
BID	22.44±1.85	22.14±1.90	1.11	0.27	22.84±1.86	21.71±1.70	4.40	<0.001	22.84±1.95	21.92±1.71	3.52	0.001
Hb	10.98±1.96	10.15±1.68	3.11	0.002	11.01±1.81	10.19±1.90	3.11	<0.01	11.27±1.66	10.15±1.92	4.32	<0.001
SA	4.36±0.43	4.25±0.46	1.72	0.09	4.37±0.48	4.25±0.40	1.79	0.07	4.38±0.46	4.26±0.43	1.88	0.06
TSP					7.29±0.67	7.11±0.72	1.87	0.06	7.31±0.70	7.13±0.69	1.84	0.07
BMI	19.02±2.33	18.48±2.35	1.61	0.11					20.36±1.84	17.40±1.61	13.16	<0.001

Abbreviations Undernut.: undernutrition; Age (years); Ht, Wt: body height (cm) and weight (kg); Circumferences (cm) MUAC: mid-upper arm; WC: waist; HC: hip; CC: calf; CN: chest normal. Skinfolds (mm) BSK: biceps; TSK: triceps; CSK: calf; SBSK: sub-scapular; SISK: supra-iliac. Diameters (cm) BDH: bi-epicondylar diameter of humerus and BDF: of femur; BAD: bi-acromial; BID: bi-iliac (BID). Hb: haemoglobin (gm/dl); SA: serum albumin (gm/dl); TSP: total serum protein (gm/dl); BMI: body mass index (kg/m^2).

for MUAC classification), Wt., MUAC (only for BMI classification), WC, HC, CC, CN, BSK, TSK, CSK, SBSK, BDH, Hb and BMI (only for MUAC classifications) were significantly different between two nutritional groups.

Further, in discriminant function analysis, initially, age, Ht., Wt., WC, HC, CC, CN, BSK, TSK, CSK, SBSK, BDH and Hb were considered as independent variables as the mean values of these variables were found significantly different between two nutritional groups. Next, stepwise discriminant analysis was carried out to determine the best combinations of the independent variables.

Table 5 describes the result of one way ANOVA to test the equality of mean values of selected independent variables in stepwise discriminant function analysis. In the ANOVA table, the smaller Wilks's Lambda indicates higher contribution of the respective independent variable in discriminating two groups (here undernutrition and normal) of the dependent variable (nutritional status). It was observed that according to the TSP classification, Hb had the highest contribution in discriminating two groups (undernutrition and normal) of dependent variable, followed by CC. Whereas, according to the BMI and MUAC classification, Wt. had significantly higher contribution in discriminating two groups of dependent variable.

Table 6 describes the eigenvalue, percentage of variance and canonical correlation in the stepwise discriminant

Table 5. Test of equality of mean values of selected independent variables between two nutritional groups (normal and undernutrition) in discriminant function analysis

IV#	TSP classification			BMI classification			MUAC classification		
	Wilks' Lambda	*F*	*p*-value	Wilks' Lambda	*F*	*p*-value	Wilks' Lambda	*F*	*p*-value
Age	0.99	1.09	0.29	0.99	0.48	0.49	0.99	0.72	0.39
Ht	1.00	0.003	0.95	0.98	3.43	0.06	0.95	11.06	0.001
Wt	0.99	1.57	0.21	0.53	171.46	<0.001	0.56	156.67	<0.001
WC	0.99	0.68	0.41	0.78	56.09	<0.001	0.79	52.84	<0.001
HC	0.99	0.34	0.56	0.88	26.57	<0.001	0.78	53.64	<0.001
CC	0.96	9.12	0.003	0.73	70.78	<0.001	0.73	71.52	<0.001
BSK	1.00	0.08	0.77	0.88	26.67	<0.001	0.87	27.98	<0.001
TSK	1.00	0.001	0.97	0.91	18.92	<0.001	0.90	21.25	<0.001
CSK	0.99	0.34	0.56	0.93	14.52	<0.001	0.93	15.28	<0.001
Hb	0.95	9.68	0.002	0.95	9.65	0.002	0.91	18.64	<0.001

#IV – Independent variables; Abbreviations: Ht, Wt: body height (cm) and weight (kg); Circumferences (cm) WC: waist; HC: hip; CC: calf. Skinfolds (mm) BSK: biceps; TSK: triceps; CSK: calf. Bioindicator Hb: haemoglobin (gm/dl).

Table 6. Result of canonical discriminant function of dependent variable (nutritional status) according to TSP, BMI and MUAC classifications

Classifications	Function	Eigenvalue	% of Variance	Canonical correlation
TSP	1	0.106	100	0.309
BMI	1	1.897	100	0.809
MUAC	1	1.227	100	0.742

function analysis. There was only two groups (normal and undernutrition) of the dependent variable (nutritional status) according to each classification (TSP, BMI and MUAC) and therefore, a single discriminant function was created for each classification. The eigenvalue describes how best discriminating ability the respective function possesses; larger eigenvalue indicates higher proportion of variance of the dependent variable can be explained by that function. It was observed that, the eigenvalue was highest for BMI classification (1.897) followed by MUAC (1.227) and TSP (0.106) classification; therefore, the discriminant function in BMI classification explained higher proportion of variance of the dependent variable (nutritional status) than other two classifications (TSP and MUAC). On the other, canonical correlation is the measure of association between the discriminant function and the dependent variable (nutritional status) and higher correlation value indicates the better association between them. In the present study, it was observed that canonical correlation was highest for BMI (0.809), followed by MUAC (0.742) and TSP (0.309) classification, therefore, the association between the discriminant function and the dependent variable was highest according to BMI classification.

Table 7 gives the values of Fisher's coefficients of stepwise discriminant function analysis and also assesses how well the Fisher's classification function coefficients were classified between the groups. The coefficients were used to construct a discriminant function for each group, i.e. normal and undernutrition.

For TSP classification,

$$\text{Normal} = -577.59 + (0.18 \times \text{Age}) + (6.95 \times \text{Ht.}) + (-7.40 \times \text{Wt.}) + (2.26 \times \text{WC}) + (0.92 \times \text{HC}) + (3.87 \times \text{CC}) + (1.72 \times \text{BSK}) + (2.75 \times \text{TSK}) + (1.39 \times \text{CSK}) + (2.32 \times \text{Hb}) \quad (1)$$

$$\text{Undernutritio} = -576.99 + (0.18 \times \text{Age}) + (6.98 \times \text{Ht.}) + (-7.38 \times \text{Wt.}) + (2.24 \times \text{WC}) + (0.93 \times \text{HC}) + (3.72 \times \text{CC}) + (1.63 \times \text{BSK}) + (2.86 \times \text{TSK}) + (1.36 \times \text{CSK}) + (2.10 \times \text{Hb}) \quad (2).$$

Table 7. Fisher's classification coefficients of discriminant function analysis to predict nutritional status

IV*	TSP classification		BMI classification		MUAC classification	
	Normal	Undernutrition	Normal	Undernutrition	Normal	Undernutrition
Age	0.18	0.18	0.12	0.10	0.20	0.18
Ht	6.95	6.98	8.33	8.81	6.79	6.98
Wt	−7.40	−7.38	−9.83	−10.70	−6.96	−7.40
WC	2.26	2.24	2.27	2.28	2.23	2.25
HC	0.92	0.93	1.06	1.11	1.00	0.92
CC	3.87	3.72	3.57	3.49	3.88	3.79
BSK	1.72	1.63	2.42	2.68	1.46	1.68
TSK	2.75	2.86	3.23	3.38	2.85	2.81
CSK	1.39	1.36	1.06	0.95	1.48	1.37
Hb	2.32	2.10	1.95	1.86	2.51	2.19
Constant	−577.59	−576.99	−621.61	−659.39	−580.77	−576.87

*IV – Independent variables; Abbreviations: Ht, Wt: body height (cm) and weight (kg); Circumferences (cm) WC: waist; HC: hip; CC: calf. Skinfolds (mm) BSK: biceps; TSK: triceps; CSK: calf. Bioindicator Hb: haemoglobin (gm/dl).

Table 8. Fisher's classification of nutritional status of different category

Classification category			Predicted: Normal	Predicted: Undernutrition	Total	Correct classification percentage
TSP						
Observed	n	Normal	74	43	117	63.6%
		Undernutrition	29	52	81	
	%	Normal	63.2	36.8	100	
		Undernutrition	35.8	64.2	100	
BMI						
Observed	n	Normal	103	5	108	97.0%
		Undernutrition	1	89	90	
	%	Normal	95.4	4.6	100	
		Undernutrition	1.1	98.9	100	
MUAC						
Observed	n	Normal	72	14	86	84.8%
		Undernutrition	16	96	112	
	%	Normal	83.7	16.30	100	
		Undernutrition	14.3	85.70	100	

Equations (1) and (2) have to be calculated for each case to get the normal or undernutrition value and the case will be classified for which computed value will be higher. For example, if equation (1) gives the higher value for a particular case, then the case will be classified as normal.

Similarly, for BMI and MUAC, equations were developed for each (described in table 7) and calculated as mentioned above.

Table 8 describes strength of classification of different classification methods in assessing nutritional status. It was observed that the percentage of correct classification was highest by BMI classification (97.0%), followed by MUAC classification (84.8%) and lowest by TSP classification (63.6%).

Discussion

Nutritional assessment in the population level is a serious concern in the developing countries like India. Literatures reveal 4 conventional methods, but efficacy of the methods have not been tested well with the population data. Present study is an exercise to compare three widely used methods (i.e. one biochemical and two anthropometric measurements and/or index) and thereby to find out the most effective method to assess the nutritional status in the population level. Biochemical parameters are believed to have precision and objectivity and useful in detecting early changes in body metabolism and nutrition before the appearance of clinical signs and symptoms. However, it is very expensive and needs clinical laboratory set-up. On the other, anthropometric measurements and index were reported to be very useful in the field settings as it is less expensive, less time consuming and needs minimal expertise. Therefore, statistical tools like discriminant function analysis was adopted to compare and predict the most effective method for nutritional status assessment.

Result of the present study showed that TSP classified 38.1% male and 43%

female as undernourished, whereas BMI showed 34.5% male, 53.5% female as undernourished and MUAC showed 45.2% male, 64.9% female as undernourished. It clearly indicates that the frequency of undernutrition was higher according to both BMI and MUAC classification than the TSP classification. TSP indicates only the protein reserve of the body, which has been assimilated within the blood from diet. On the other, BMI and MUAC provides a picture of body composition as well as the degrees of nutrition (Jelliffe 1966). Thus the later classification classify more number of individuals as undernourished.

However, three different methods showed different frequencies of undernutrition for the same data set. To evaluate the strength of classification, discriminant function analysis was performed. The analysis showed that independent variables like Wt., WC, HC, CC, BSK, TSK, CSK and Hb had significant contribution in discriminating two groups (i.e. normal and undernutrition) of nutritional status according to three classifications (TSP, BMI and MUAC) (Table 5). Thus these independent variables used to create model equations to predict the nutritional status of each individuals considering TSP, BMI and MUAC as dependent variables.

The model of discriminant fuction analysis estimated the highest strength of correct classification was by BMI (97.0%) followed by MUAC (84.80%) and TSP (63.60%) (Table 8). However, it was assumed that TSP has had the highest strength because of its objectivity to assess nutritional deficiencies. But, in the present study, as the study group was not acutely undernourished (the mean TSP 7.21±0.70 gm/dl), therefore TSP may not be an ideal tool for assessing nutritional status. On the other, MUAC is an uni-dimensional measurement and often changes with occupational variation and have other environmental effects (Collins 1996; Collins et al. 2000). So it showed less strength of correct classification than BMI. Whereas, BMI provides the idea of body mass as well as linearity. It is highly correlated with fat and fat-free mass and so, the protein and fat reserves of whole body can well be estimated by BMI (Lee et al. 2003). Thus BMI showed highest strength in assessing nutritional status.

Many studies (Young et al. 1978; Killingsworth 1979; Woods 1982; Putignano et al. 2000; Roongpisuthipong et al. 2001; Knox 2003; Laky et al. 2008) revealed that biochemical assessment of nutritional status is a clinically relevant method for evaluating nutritional status which has been used to identify any specific deficiency in patients. Similar conclusion was made by Du et al. (2017) in a study on nutritional assessment of cancer patients. On the other, anthropometric measurements primarily carried out in large-scale population level because it is non-invasive, less expensive and needs minimal expertise (Toriola 1990; Chamruengsri et al. 1991; Chaturvedi et al. 1994; Collins 1996; Ferro-Luzzi et al. 1996; Toole 1996; Collins et al. 2000). Therefore, using anthropometric measurements, BMI is sufficiently capable for the nutritional assessment in population level because it is a multi-dimentoinal measurement and can predict the trend of nutritional status much before the acute nutritional deficiency.

Conclusion

The present study compared three classification scale of nutritional assessment – TSP, BMI and MUAC and thereby tried to find out the most accurate one in a population data. From the result of the present study it may be argued that the BMI is the most effective method in large scale population survey because it is helpful to assess the chronic change of nutritional status in human body and therefore can be used as a screening method for field level study. However, the number of sample size of the present study was very small on which the calculation was made, and it is based on a specific group, therefore, more studies in other populations with larger sample size would be required to justify the present findings.

Finally, it is expected that scientific ventures will continue to establish the present result with other study population and then that will provide a comprehensive understanding over the phenomena.

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Authors' contributions

AB collected the data, carried out the statistical analysis and drafted the manuscript for the present study. AB, SM and SKR participated in study design and manuscript preparation.

Conflict of interest

There is no conflict of interests regarding the publication the article.

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